POWER

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Antiques

I AM up in a country where antiques are much in evidence. Every town where tourists pass or sojourn has its *Antique Shoppe*, and collectors pester the populance with pleas to be allowed to rummage cellars and garrets for some hold-over from a former generation.

What is behind this craze for the ancient? Why are people willing to pay exorbitant prices for things that serve their purpose no better than the modern product?

There are those who buy antiques because it is the thing to do. They would not buy a used car or a second-hand piano, but they will pay four prices for a glued-up rocking chair or a faded rug because it makes the room look like a picture in a magazine.

But I wonder if the thing behind the real sentiment for antiques is not an innate appreciation of the human labor and talent that is preserved in them.

It is not because they are old. A stone from the field is older and has been through more interesting experiences, but it is not collected.

It is not appearance, design, fit and finish. Machine-made reproductions of antique patterns have all these.

But there is a sense of admiration of and reverence for the work built into the specimen, for the patient skill that produced with hand tools and loving craftsmanship the piece that has withstood the ravages of time and the vicissitudes of usage by several generations.

And when one knows something of the personality of the maker or of those who have owned and used the "piece," the interest is multiplied by the association, but in this case becomes more in the nature of that attaching to a reliquary than to a simple antique.

F. R. Low

Large Economies Result from Using Steam-Turbine Loading Schedules

By Amory R. Haynes

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POWER plants frequently must operate more or less of the time with excess capacity, necessitating partial loading of units. Where this condition obtains, the division of load among units for maximum plant efficiency should be investigated, an operating schedule devised, and units selected and loaded in accordance therewith, as otherwise considerable steam may be wasted unknowingly.

No knowledge of mathematics other than arithmetic is required in the following method of making up an operating schedule, which was originally devised in the study of waterwheel operation. ("Economical Operation of Hydraulic Turbines," by A. R. Haynes, *Electric Light & Power*, October, 1923.) It has been found applicable to steam turbines, and may appeal to operators who have not this information.

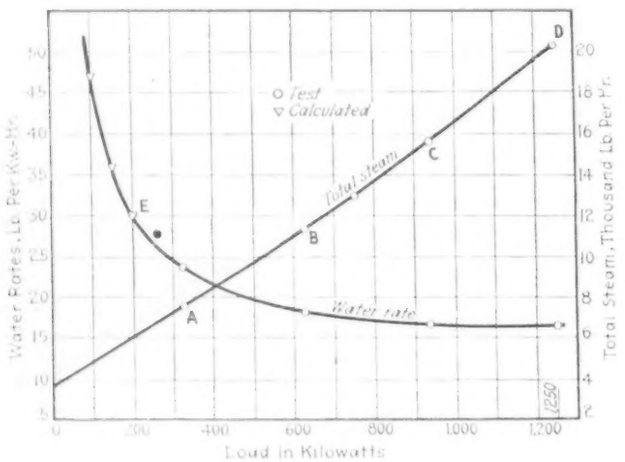


Fig. 1—Water-rate and total-steam curves for unit No. 2

Steam condition 175 lb. gage, 100 deg. F. superheat, expanded to a 28-in. vacuum.

An operating schedule is built up from the water rates of the units. If test data are not available, the water rates of similar units can no doubt be obtained from the manufacturer.

A station with four units has been assumed. The turbines operate with 175 lb. steam pressure, 100 deg. F. superheat, and 28-in. vacuum. The turbines are equipped with secondary valves which may be opened in emergency to obtain approximately 10 per cent increase in capacity. This feature, however, being of an emergency nature, will not be considered as the schedule is to be devised for normal operation. The generators are rated at 80 per cent power-factor. In the accompanying table of water rates the figures are for pounds of steam per kilowatt-hour and the loads are for kilowatts delivered at the switchboard.

These data have been plotted as curves in Figs. 1 and 2. Fig. 1 shows the characteristics of unit No. 2. Total steam per hour is found from the product of load and water rate. Thus with unit No. 2 carrying a load of 312 kw., the water rate is 23.5 lb. of steam per kilowatt-hour. It will therefore require 312 × 23.5 lb., or 7,332 lb., of steam per hour, which point may be located on a sheet of cross-section paper. At one-half load, or 625 kw., the water rate is 18 lb. and the total steam consumption per hour at this load is 625 × 18 lb. or 11,250 lb.

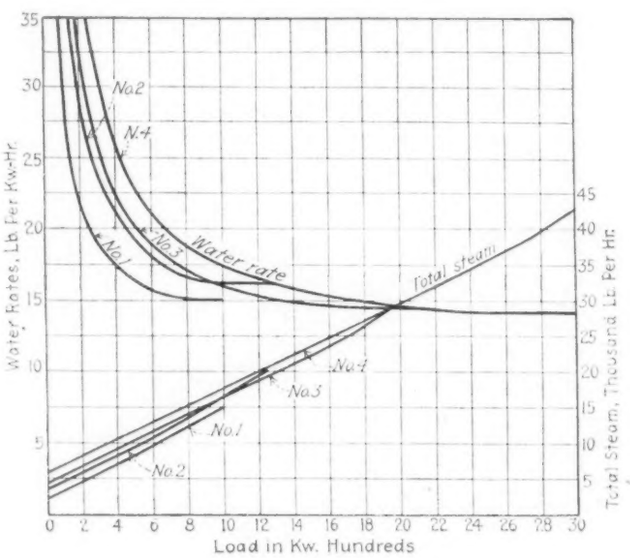


Fig. 2—Water-rate and total-steam curves for units Nos. 1, 2, 3 and 4

Steam condition same as given in Fig. 1.

In a like manner the steam consumption per hour for three-quarter and full load is found to be 15,469 and 20,250 lb. respectively. These four values are shown as points *A*, *B*, *C* and *D* on the total steam-per-hour curve. When these points have been plotted, a curve may be drawn through them. It will be noted that this curve is nearly a straight line, which is characteristic of all steam turbines.

After three or four points have been located on the upper three-quarters of the curve, it can be assumed to be a straight line and may be extended as such to obtain the total steam all the way down to no load. Four values for the water-rate curve are given in Table I, but others may be calculated from the total steam curve. For example, at 200-kw. load, the total steam per hour is about 6,000 lb. and the rate per kilowatt-hour is 6,000 ÷ 200 = 30 lb., which is shown as calculated point *E* on the water-rate curve. On these curves, test data points are indicated by circles and computed points by triangles.

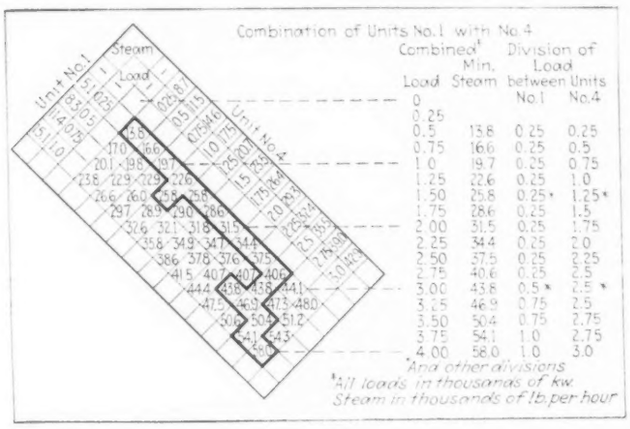


Fig. 3—Chart showing the most efficient loading of units 1 and 4

TABLE I—WATER RATES OF UNITS

Unit	Size, kw.	Loads 2/5	1/2	3/4	Full
1	1,000	17.6	16.6	15.2	15.1
2	1,250	(23.5 at 312 kw.)	18.0	16.5	16.2
3	2,000	17.2	16.2	14.8	14.7
4	3,000	16.7	15.7	14.4	14.3

In Fig. 2 total-steam-per-hour and water-rate curves for all four units are given. From these curves the load-steam data in Table II were obtained. For instance, at a 250-kw. load, unit No. 1 requires about 5,100 lb. of steam per hour; unit No. 2, about 6,600; No. 3 unit, about 7,200; and unit No. 4, about 8,700 pounds.

From Fig. 2 and Table II it can be seen that for loads within its capacity unit No. 1 is the most economical turbine. From this it might be assumed that in combination with another unit, unit No. 1 should be operated fully loaded. For example, with a station load of 1,250 kw. and units Nos. 1 and 3 in operation, if No. 1 unit were fully loaded to 1,000 kw., it would require 15,100 lb. of steam per hour and, with 250 kw. on unit No. 3, about 7,200 lb. of steam would be required per hour, or a total of 15,100 + 7,200 = 22,300 lb. per hour for both machines.

Whether this distribution of load is the more economical or not depends on the shape of the efficiency curves of the respective units. With the machines in question this is not the most economical distribution of load, as with these particular units, if 250 kw. were carried on unit No. 1 and 1,000 kw. on unit No. 3, the steam requirements per hour would be 5,100 lb. and 16,200 lb. respectively, or a total of 21,300 lb., which is an improvement of 22,300 — 21,300 = 1,000 lb. of steam per hour over the previous assumption of load allotments. Preferably, if load conditions permitted, the entire load of 1,250 kw. might be carried on unit No. 3 and unit No. 1 shut down, since a turbine cannot be floated on the line without a certain amount of steam passing through it to prevent an excessive rise of temperature in the wheels. In this case the steam consumption of unit No. 3 carrying 1,250 kw. would be 19,200 lb. of steam per hour, or a saving of 3,100 lb. of steam over the first assumption.

The station operator or engineer can vary the apportionment of load among units without changing the frequency (speed) by adjusting the turbine governor settings. With a constant station load, the total amount of steam used by the turbines will vary with the division of load assigned to the units and the individual efficiency of each machine at these loads. The necessity for providing the operator or engineer with an operating schedule so that he will know not only which units should be operated, but what the individual machine loads should be for maximum economy, is obvious from the foregoing.

TABLE II—STEAM CONSUMPTION OF UNITS

Load, Kw.	Thousands of Pounds of Steam per Hour — Unit No. 1	Unit No. 2	Unit No. 3	Unit No. 4
250	5.1	6.6	7.2	8.7
500	8.3	9.6	10.2	11.5
750	11.4	12.9	13.2	14.6
1,000	15.1	16.4	16.2	17.5
1,250	....	20.2	19.2	20.7
1,500	....	....	22.2	23.5
1,750	....	....	25.7	26.4
2,000	....	....	29.4	29.3
2,250	....	....	....	32.4
2,500	....	....	....	35.5
2,750	....	....	....	39.0
3,000	....	....	....	42.9

The consumption of steam may be studied by the construction of charts similar to Fig. 3. This chart is in the form of a rectangle with its sides placed at an angle of 45 deg. to the horizontal. The use of cross-section paper greatly simplifies the construction. Along the upper sides of the rectangle are placed values of loads and steam consumption. Thus on the upper right are found loads ranging from 250 to 3,000 kw. in steps of 250 kw., with the corresponding steam consumption for each of these loads as obtained for unit No. 4 from Table II. Similarly, the values of load and steam for unit No. 1 are given on the upper left side. The spaces for zero load are left blank. As previously noted, a turbine should not be operated at no load—some steam should be admitted to keep the blading cool. It has been assumed that no unit in practical operation will be assigned a load of less than 250 kw. and the schedule will

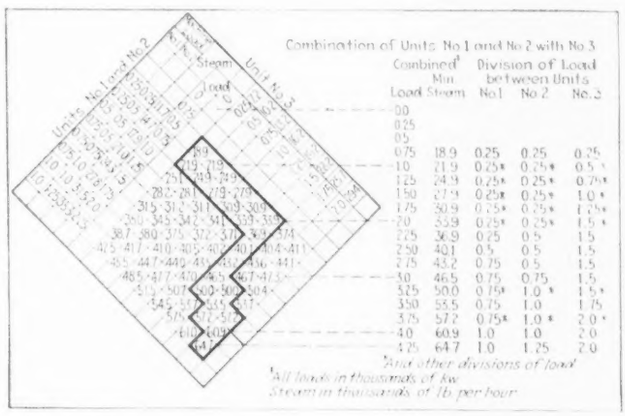


Fig. 4—Most efficient combined loading of units 1, 2 and 3

The station operator or engineer can vary the apportionment of load among units without changing the frequency (speed) by adjusting the turbine governor settings. With a constant station load, the total amount of steam used by the turbines will vary with the division of load assigned to the units and the individual efficiency of each machine at these loads. The necessity for providing the operator or engineer with an operating schedule so that he will know not only which units should be operated, but what the individual machine loads should be for maximum economy, is obvious from the foregoing.

The consumption of steam may be studied by the construction of charts similar to Fig. 3. This chart is in the form of a rectangle with its sides placed at an angle of 45 deg. to the horizontal. The use of cross-section paper greatly simplifies the construction. Along the upper sides of the rectangle are placed values of loads and steam consumption. Thus on the upper right are found loads ranging from 250 to 3,000 kw. in steps of 250 kw., with the corresponding steam consumption for each of these loads as obtained for unit No. 4 from Table II. Similarly, the values of load and steam for unit No. 1 are given on the upper left side. The spaces for zero load are left blank. As previously noted, a turbine should not be operated at no load—some steam should be admitted to keep the blading cool. It has been assumed that no unit in practical operation will be assigned a load of less than 250 kw. and the schedule will

be devised on this basis. Therefore the smallest load on any unit will be taken as 250 kw. The size of the increment load steps is immaterial as long as equal steps are taken for both units. With larger units, steps of 500 or even 1,000 kw. might prove advantageous to reduce the size of the charts and still furnish the necessary operating data.

The load on the system should be at least 500 kw. to have two units in operation, which allows the minimum machine load considered in Fig. 3. With 500-kw. load on units Nos. 1 and 4, Fig. 3, there is only one load combination that can be considered; namely, 250 kw. on each unit. This load on unit No. 1 requires 5,100 lb. of steam, and on unit No. 4 the steam consumption is 8,700 lb., or a total of 13,800 lb., which is shown in the diagram in the square where the two diagonal rows intersect.

For a load of 750 kw. there are two combinations that might be used, 500 kw. on unit No. 4 and 250 on unit No. 1, or vice versa. The first combination requires 11,500 lb. of steam for No. 4 and 5,100 for unit No. 1, or a total of 16,600 lb. For the latter combination the steam consumption is 8,300 lb. (500 kw.) for unit No. 1 and 8,700 lb. (250 kw.) for unit No. 4, making a total of 17,000 lb. In each case the total amount of steam is placed in the square corresponding to the diagonal rows headed by its component parts.

There are three different combinations of loading the units for 1,000 kw. and four for 1,250 kw. or more, which is the maximum number, since full rated load, 1,000 kw., of unit No. 1 is reached. The steam consumption for all these combinations is worked out by adding the amounts of steam shown at the head of the diagonal rows in which the square lies.

When all combinations have been worked out and entered, the values of steam consumption for a given station load, with various load divisions between units, will be found to fall in a horizontal line as shown in the chart. The minimum amount of steam for a particular station load may be easily seen, and the division of load between the units for this amount may be noted from the kilowatt scales for the units at the tops of the rows in which the square lies. On the chart the minimum steam values are surrounded by the heavy line. To make these values more readily available, a table may be added to the chart as shown at the right.

For each combination of two units a chart similar to Fig. 3 should be constructed. The data from these charts can then be combined into a table such as Table III, which gives the proper division of load between any two units in operation. Thus with a station load of 2,500 kw. and with units Nos. 2 and 3 in operation, 1,000 kw. should be assigned to unit No. 2 and 1,500 kw. to unit No. 3 for minimum steam consumption.

After the best division of load has been worked out for the combinations of two units, charts can be made for combinations of three machines, as shown in Fig. 4. In this chart, which is for the combination of units Nos. 1, 2 and 3, it will be noted that units 1 and 2 are used

TABLE III—MINIMUM STEAM CONSUMPTION FOR COMBINATIONS OF TWO UNITS

Total 1,000's of Lb. of Steam per Hour

Station Load, 1,000's Kw.	Combinations: Units 1 and 2 — Load: No. 1	No. 2	Steam, 1,000's Lb. per Hr.	Units 1 and 3 — Load: No. 1	No. 3	Steam, 1,000's Lb. per Hr.	Units 1 and 4 — Load: No. 1	No. 4	Steam, 1,000's Lb. per Hr.	Units 2 and 3 — Load: No. 2	No. 3	Steam, 1,000's Lb. per Hr.	Units 2 and 4 — Load: No. 2	No. 4	Steam, 1,000's Lb. per Hr.	Units 3 and 4 — Load: No. 3	No. 4	Steam, 1,000's Lb. per Hr.
0.5	0.25	0.25	11.7	0.25	0.25	12.3	0.25	0.25	13.8	0.25	0.25	13.8	0.25	0.25	15.3	0.25	0.25	15.9
0.75	0.25	0.5	14.7	0.25	0.5	15.3	0.25	0.5	16.6	0.25	0.5	16.8	0.25	0.5	18.1	0.25	0.5	18.7
1.0	0.5	0.5	17.9	0.25	0.75	18.3	0.25	0.75	19.7	0.25	0.75	19.8	0.25*	0.75*	21.1	0.25*	0.75*	21.7
1.25	0.75	0.5	21.0	0.25	1.0	21.3	0.25	1.0	22.6	0.25	1.0	22.8	0.25	1.0	24.1	0.25	1.0	24.7
1.5	0.75	0.75	24.3	0.25	1.25	24.3	0.25	1.25	25.8	0.25	1.25	25.8	0.25*	1.25*	27.1	0.25*	1.25*	27.7
1.75	0.75	1.0	27.8	0.25	1.5	27.3	0.25	1.5	28.6	0.25	1.5	28.8	0.25	1.5	30.1	0.25	1.5	30.7
2.0	1.0	1.0	31.5	0.5	1.5	30.5	0.25	1.75	31.5	0.5	1.5	31.8	0.25	1.75	33.0	0.25	1.75	33.6
2.25	1.0	1.25	35.3	0.75	1.5	33.6	0.25	2.0	34.4	0.75	1.5	35.1	0.25	2.0	35.9	0.25	2.0	36.5
2.5	....	....	....	0.75	1.75	37.1	0.25	2.25	37.5	1.0	1.5	38.6	0.5	2.0	38.9	0.5	2.0	39.5
2.75	....	....	....	1.0	1.75	40.8	0.25	2.5	40.6	1.0	1.75	42.1	0.5	2.25	42.0	0.75	2.0	42.5
3.0	....	....	....	1.0	2.0	44.5	0.5	2.5	43.8	1.0	2.0	45.8	0.5	2.5	45.1	1.0	2.0	45.5
3.25	....	....	....	....	....	....	0.75	2.5	46.9	1.25	2.0	49.6	0.75	2.5	48.4	1.25	2.0	48.5
3.5	....	....	....	....	....	....	0.75	2.75	50.4	....	....	....	0.75	2.75	51.9	1.5	2.0	51.5
3.75	....	....	....	....	....	....	1.0	2.75	54.1	....	....	....	1.0	2.75	55.4	1.5	2.25	54.6
4.0	....	....	....	....	....	....	1.0	3.0	58.0	....	....	....	1.25	2.75	59.2	1.5	2.5	57.7
4.25	....	....	....	....	....	....	....	....	....	....	....	....	1.25	3.0	63.1	1.5	2.75	61.2
4.5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.75	2.75	64.7
4.75	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.0	2.75	68.4
5.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.0	3.0	72.3

* Approximate.

TABLE IV—MINIMUM STEAM CONSUMPTION—COMBINATIONS OF THREE UNITS

Total 1,000's of Lb. of Steam per Hour

Station Load 1,000's of Kw.	Combinations: Units 1, 2 and 3 — Load: No. 1	No. 2	No. 3	Steam, 1,000's Lb. per Hr.	Units 1, 2 and 4 — Load: No. 1	No. 2	No. 4	Steam, 1,000's Lb. per Hr.	Units 1, 3 and 4 — Load: No. 1	No. 3	No. 4	Steam, 1,000's Lb. per Hr.	Units 2, 3 and 4 — Load: No. 2	No. 3	No. 4	Steam, 1,000's Lb. per Hr.
0.75	0.25	0.25	0.25	18.9	0.25	0.25	0.25	20.4	0.25	0.25	0.25	21.0	0.25	0.25	0.25	22.5
1.0	0.25	0.25	0.5	21.9	0.25	0.25	0.5	23.2	0.25	0.25	0.5	23.8	0.25	0.25	0.5	25.3
1.25	0.25	0.25	0.75	24.9	0.25	0.25*	0.75*	26.2	0.25	0.25*	0.75*	26.8	0.25	0.25*	0.75*	28.3
1.5	0.25	0.25	1.0	27.9	0.25	0.25	1.0	29.2	0.25	0.25	1.0	29.8	0.25	0.25	1.0	31.3
1.75	0.25	0.25	1.25	30.9	0.25	0.25*	1.25*	32.2	0.25	0.25*	1.25*	32.8	0.25	0.25*	1.25*	34.3
2.0	0.25	0.25	1.5	33.9	0.25	0.25	1.5	35.2	0.25	0.25	1.5	35.8	0.25	0.25	1.5	37.3
2.25	0.25	0.5	1.5	36.9	0.25	0.25	1.75	38.1	0.25	0.25	1.75	38.7	0.25	0.25	1.75	40.2
2.5	0.5	0.5	1.5	40.1	0.25	0.25	2.0	41.0	0.25	0.25	2.0	41.6	0.25	0.25	2.0	43.1
2.75	0.75	0.5	1.5	43.2	0.25	0.5	2.0	44.0	0.25	0.5	2.0	44.6	0.25	0.5	2.0	46.1
3.0	0.75	0.75	1.5	46.5	0.25	0.5	2.25	47.1	0.25	0.75	2.0	47.6	0.25	0.75	2.0	49.1
3.25	0.75	1.0	1.5	50.0	0.25	0.5	2.5	50.2	0.25	1.0	2.0	50.6	0.25	1.0	2.0	52.1
3.5	0.75	1.0	1.75	53.5	0.5	0.5	2.5	53.4	0.25	1.25	2.0	53.6	0.25	1.25	2.0	55.1
3.75	0.75	1.0	2.0	57.2	0.75	0.5	2.5	56.5	0.25	1.5	2.0	56.6	0.25	1.5	2.0	58.1
4.0	1.0	1.0	2.0	60.9	0.75	0.75	2.5	59.8	0.25	1.5	2.25	59.7	0.5	1.5	2.0	61.1
4.25	1.0	1.25	2.0	64.7	0.75	0.75	2.75	63.3	0.25	1.5	2.5	62.8	0.5	1.5	2.25	64.2
4.5	....	....	....	....	0.75	1.0	2.75	66.8	0.5	1.5	2.5	66.0	0.5	1.5	2.5	67.3
4.75	....	....	....	....	1.0	1.0	2.75	70.5	0.75	1.5	2.5	69.1	0.75	1.5	2.5	70.6
5.0	....	....	....	....	1.0	1.25	2.75	74.3	0.75	1.5	2.75	72.6	1.0	1.5	2.5	74.1
5.25	....	....	....	....	1.0	1.25	3.0	78.2	0.75	1.75	2.75	76.1	0.75	1.75	2.75	77.6
5.5	....	....	....	....	....	....	....	....	0.75	2.0	2.75	79.8	1.0	1.75	2.75	81.1
5.75	....	....	....	....	....	....	....	....	1.0	2.0	2.75	83.5	1.0	2.0	2.75	84.8
6.0	....	....	....	....	....	....	....	....	1.0	2.0	3.0	87.4	1.25	2.0	2.75	88.6
6.25	....	....	....	....	....	....	....	....	....	....	....	....	1.25	2.0	3.0	92.5

* Approximate.

jointly, the minimum steam values from the combination of unit No. 1 with No. 2 are set down on the left top of the chart and combined with unit No. 3 on the right. The minimum load that can be carried by the three units is 750 kw., and this has to be carried 250 kw. on each machine, in order that no turbine may overheat.

With a combined load of 500 kw. on units 1 and 2 the steam consumption is 11,700 lb., and 250 kw. on unit No. 3 requires 7,200 lb., so that 750 kw. combined load on the three machines takes the sum of 11,700 and 7,200, or 18,900 lb. of steam, as entered in the chart. With a station load of 1,000 kw. two combinations are possible: 250 kw. on each of units 1 and 2, and 500 on unit No. 3, or a combined load of 750 kw. on Nos. 1 and 2, and 250 kw. on No. 3. The first combination has a steam consumption of 11,700 + 10,200 = 21,900 lb.; the second requires 14,700 + 7,200 = 21,900 lb., which happens to come out the same amount as the first combination, as shown in the chart. The remainder of the chart is worked out and the values set down in a similar manner.

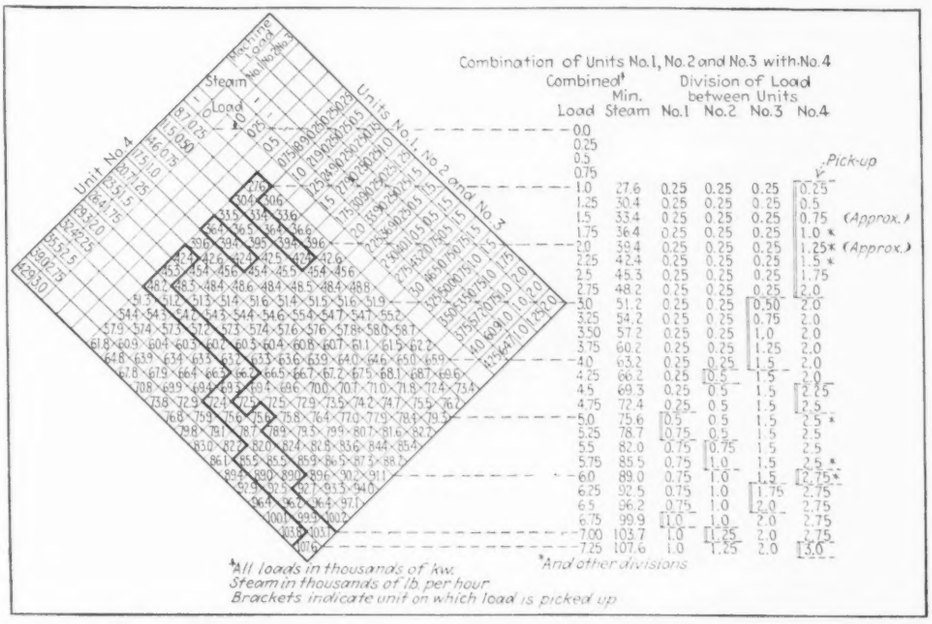


Fig. 5—Chart giving the most efficient combination of loads on units 1, 2, 3 and 4

After charts have been worked out for the minimum steam consumption for all combinations of units with three in operation, these values may be arranged as in Table IV. This table is then available for use by the operator or engineer in adjusting the load on the units to obtain the highest economy.

Complete information for loading with all four units in operation is given in Fig. 5.

Inspection of the loading tables for the various combinations shows that for minimum steam consumption at partial loads, better economy is obtained by carrying the bulk of the load on some particular unit. Thus in Table III in the loading of units Nos. 1 and 4 in combination, the bulk of the load is carried on No. 4 machine up to a combined load of 2,750 kw. before any increase in load is made on No. 1 machine, which has been operating at minimum load.

On the other hand, changes in station load should be taken care of by picking up or dropping load in a definite manner on certain units, depending on the combination involved. Take for instance, in Table IV, with units Nos. 2, 3 and 4 in operation supplying a station load of 2,500 kw. An increase of 250 kw. in station load above this value should be picked up on unit No. 3, while if the station load decreases 250 kw. below 2,500, then this decrease should be dropped from No. 4 to retain the most economical loading.

Due to variations in load of a governing station, it is not to be expected that the loads of individual machines can be kept strictly allotted according to schedule. However, the closer loads are held to schedule, the better the over-all economy of the station will be. As a matter of interest the maximum amount of steam required by the turbines has been computed for the most uneconomical distribution of load among units. This is shown in Table V, and as noted for 4,500 kw., there is a difference of 4,100 lb. between the best and poorest manner of apportioning the load. At a water rate of 14.9 lb., 4,100 lb. of steam per hour is the equivalent of 275 kilowatts.

In many small plants load is usually divided equally among units of the same size, with probably a little more on larger units. A station operating several units each at 50 to 75 per cent load is probably wasting considerable steam. Referring again to Table V, the steam consumption for the best and poorest division of loads is given. The saving to be obtained with any other division of load among units will be less than the maximum given in the table for the particular station load, but no doubt may prove to be considerable if maintained over a large portion of the day.

TABLE V.—MAXIMUM AND MINIMUM STEAM CONSUMPTION, ALL FOUR UNITS IN OPERATION

Load 1,000's Kw.	Maximum Steam, 1,000's Lb. per Hr.	Minimum Steam, 1,000's Lb. per Hr.	Saving Steam, 1,000's Lb. per Hr.
1.0	27.6	27.6	....
1.25	30.8	30.4	0.4
1.5	33.9	33.4	0.5
1.75	37.6	36.4	1.2
2.0	41.2	39.4	1.8
2.25	44.4	42.4	2.0
2.5	47.5	45.3	2.2
2.75	51.2	48.2	3.0
3.0	54.2	51.2	3.0
3.25	57.2	54.2	3.0
3.5	60.2	57.2	3.0
3.75	63.4	60.2	3.2
4.0	66.6	63.2	3.4
4.25	69.7	66.2	3.5
4.5	73.4	69.3	4.1
4.75	76.2	72.4	3.8
5.0	79.3	75.6	3.7
5.25	82.2	78.7	3.5
5.5	85.4	82.0	3.4
5.75	88.4	85.5	2.9
6.0	91.4	89.0	2.4
6.25	94.4	92.5	1.9
6.5	97.6	96.2	1.4
6.75	100.8	99.9	0.9
7.0	103.9	103.7	0.2
7.25	107.6	107.6	...

In a second article the application of the loading schedules to a typical station load curve for the day, and the selection of units and combinations will be discussed.

Supersaturation *and the* Flow of Wet Steam

PART I—SUPERSATURATION

By Professor G. A. GOODENOUGH
Professor of Mechanical Engineering, University of Illinois

POWER is proud to make available to its readers this discussion of a highly involved subject that is often alluded to in recent discussions of steam-turbine performance. Professor Goodenough has correlated extensive experimental researches in this field made by the General Electric Company, and speaks as an expert. The subject is difficult, and engineers interested in the theory of the steam turbine will welcome the brief exposition in this and one other article to follow it.

SUPERSATURATION is a phenomenon that may occur in the flow of steam through nozzles when the steam is initially wet, saturated, or only slightly superheated. In the case of flow through a turbine, the steam at some stage passes from the superheated to the wet condition. At this stage, and presumably in all succeeding stages, a greater or less degree of supersaturation

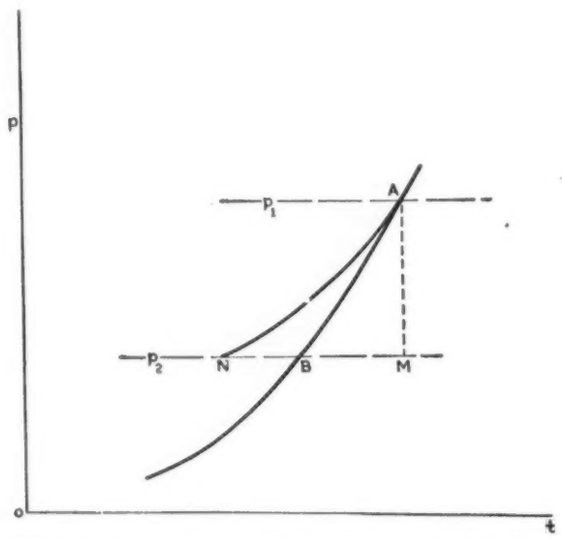


Fig. 1—Pressure-temperature diagram showing supersaturated expansion

may be present. The turbine designer is therefore interested in such questions as the amount of supersaturation, if any, the effect of supersaturation on stage efficiency, and the proper design of nozzles and buckets to take account of supersaturation.

It may be stated at the outset that supersaturation is bound up with another phenomenon, namely, the difference between the speed of the steam particles and the speed of the water particles carried along with the steam. When the steam is initially wet, the two phenomena are interlocked; in any computation both must be taken into consideration.

The proper introduction to the phenomenon of supersaturation is a study of the equilibrium of a mixture of steam and water. Such a mixture has two phases, the liquid and the gaseous; and the well known condition of equilibrium is that the temperature of the steam is the same as that of the water, and that this common temperature is uniquely determined by the pressure.

The curve *AB* in Fig. 1 shows the relation between pressure and temperature for equilibrium. A point on the curve represents the state of a mixture in equilibrium; and any change of state in which equilibrium is maintained must be represented by a movement of a point along this curve. (In the case of evaporation or condensation at constant pressure the state point remains in its initial position.) A point not on the equilibrium curve may represent a state of the mixture (or of one of the phases) but such a state is not stable. For example,

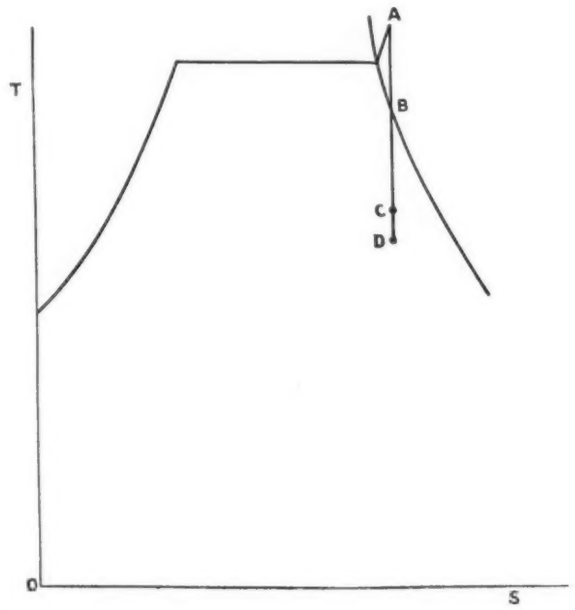


Fig. 2—Temperature-entropy diagram showing equilibrium and supersaturated expansion, also shown in Figs. 3 and 4

let point *A* represent the state of water ready to vaporize at the pressure p_1, and suppose that the pressure is suddenly reduced from p_1 to p_2. Since the temperature remains unchanged, the point *M* represents the new state of the water. This is an unstable state. The water is superheated, that is, it has a temperature higher than the equilibrium temperature corresponding to the pressure p_2. The system immediately strives to attain the equilibrium state, represented by point *B*, for the pressure p_2. By evaporation, the water is cooled until the equilibrium temperature is reached.

A point, as N, on the left of the equilibrium curve may represent the state of the steam phase after a sudden expansion from the initial state A. Slow expansion with equilibrium conditions maintained would be accompanied by condensation of part of the steam; and the path of the state point would be the segment AB of the equilibrium curve. Condensation, however, requires time; and if the drop in pressure from p_1 to p_2 occupies a time of 1/1,000th second or less, as in the flow through nozzles, condensation may not even start. In this case the steam does not receive the heat of condensation and the temperature at the end of expansion (represented by point N) is lower than the equilibrium temperature (point B) for the same pressure p_2. Again the system will strive toward equilibrium and will ultimately reach it by condensation of part of the vapor.

The steam in the state represented by point N, Fig. 1, is said to be supersaturated or undercooled. To show the relations involved more clearly, a concrete numerical example is introduced.

Consider the adiabatic expansion of steam in a turbine nozzle with the following initial conditions:

Pressure p_1 = 40 lb./in.² absolute
Temperature t_1 = 283.2° F. (corresponding to 16° superheat)
Volume v_1 = 10.77 cu.ft./lb.
Entropy s_1 = 1.6900

In Figs. 2, 3, 4, the expansion is represented on three different planes. In each figure, $ABCD$ represents frictionless adiabatic expansion under equilibrium conditions as usually assumed. The segment AB represents the part of the expansion in the region of superheat. At point B the steam is dry and saturated, and further expansion under equilibrium conditions will require condensation of some of the steam, as shown in Fig. 2. Suppose, however, that the change of state is so rapid that condensation does not appear according to schedule when the saturation curve is reached at point B. Then in Fig. 3 the point representing the state instead of turning into the equilibrium path BCD will move along path BEF continuous with AB; and the steam will become undercooled.

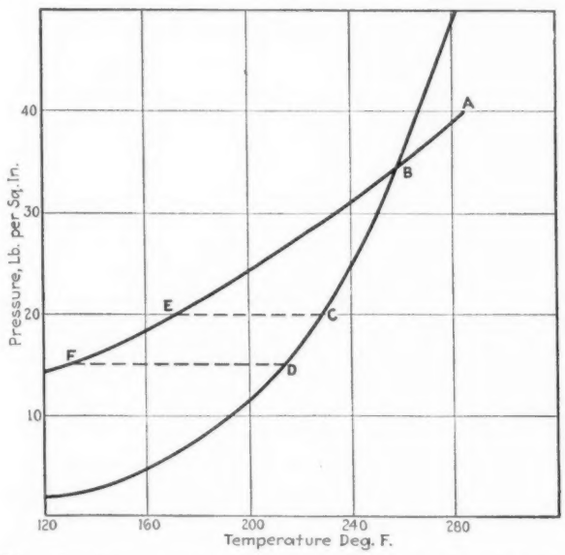


Fig. 3—Pressure-temperature diagram showing the same expansions as Figs. 2 and 4

The relation between p and T for the adiabatic expansion AB in the superheat region is given approximately by the equation

$$p^{\frac{n-1}{n}} = CT$$

in which the constant n has approximately the value 1.3. It may reasonably be assumed that the same equation applies to curve BEF.

In Fig. 4 the two changes of state are shown on the

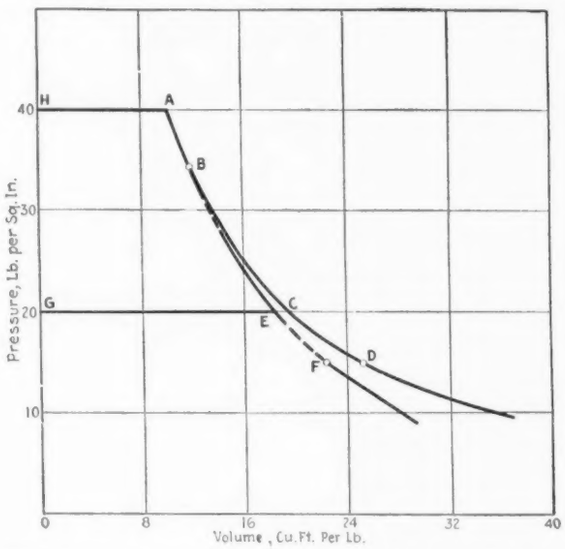


Fig. 4—Pressure-volume diagram showing the same expansions as Figs. 2 and 3

pv-plane. The approximate equation of part AB of the expansion curve is

$$pv^n = const.$$

with $n = 1.315$, and the same equation may be applied to the curve BEF. For the equilibrium expansion BCD, the value of the exponent n is about 1.13. Thus the curve BCD lies above the curve BEF, which means that for the same pressure p_2 the volume for equilibrium expansion is greater than the volume when the expansion proceeds without condensation.

The following numerical results are readily obtained. For points C and E, $p_2 = 20$ lb. per sq.in.; for points D and F, $p_2 = 15$ lb. per sq.in. Then

Temperature at point C = 228°
" " " E = 173.4°
Difference = 54.6°
Temperature at point D = 213°
" " " F = 132.7°
Difference = 80.3°
Volume at point C = 19.46 cu.ft.
" " " E = 18.245 cu.ft.

From the steam table the equilibrium pressure corresponding to $t_E = 173.4$ deg. is 6.48 lb. per sq.in.; and that for the temperature $t_F = 132.7$ deg. is 2.39 lb. per sq.in.

Certain terms may now be defined. If the steam during its expansion follows the path BEF, Figs. 3, 4, it is said to be *undercooled* or *supersaturated*. For the lower pressure $p_2 = 20$ lb., the undercooling is 54.6 deg., for the lower pressure $p_2 = 15$ lb., it is 80.3 deg. The actual pressure for state E is 20 lb., the equilibrium pressure for steam at temperature $t_E = 173.4$ deg. is 6.48 lb. The ratio 20/6.48 = 3.09 is called the *degree*

of supersaturation. For the state F, this is 15/2.39 = 6.28.

A comparison of the velocity and discharge associated with the two expansion curves $ABCD$ and $ABEF$, Fig. 4, is instructive. According to the usual law of frictionless flow, the area $ABEGH$, Fig. 4, expressed in foot-pounds gives the increase of kinetic energy of 1 lb. of flowing liquid in the change of state from A to E. The expression for this area is

$$144 \frac{n}{n-1} (p_1 v_1 - p_2 v_2)$$

and with the data given, namely, $p_1 = 40$, $v_1 = 10.77$, $p_2 = 20$, $v_2 = 18.245$, $n = 1.315$, the increase of kinetic energy is found to be 39,620 ft.lb. = 50.95 B.t.u. If the velocity in the initial state is taken as zero, the velocity at exit is

$$w = 223.7\sqrt{50.95} = 1{,}597 \text{ ft. per sec.}$$

If the equilibrium curve ABC were followed, the velocity would be

$$w' = 223.7\sqrt{i_A - i_C} = 223.7\sqrt{52} = 1{,}616 \text{ ft. per sec.}$$

The velocity 1,597 is associated with the specific volume 18.245 cu.ft. for state E, while the velocity 1,616, is associated with 19.46 cu.ft. for state C. If the area of the cross-section is F sq.ft., the discharge for the expansion ABE is

$$G = \frac{1{,}597}{18.245} F$$

and for the equilibrium expansion ABC, it is

$$G' = \frac{1{,}616}{19.46} F$$

The ratio of these is

$$\frac{G'}{G} = \frac{1{,}597}{1{,}616} \frac{19.46}{18.245} = 1.044$$

Thus expansion with undercooling (along ABE) shows a smaller velocity but a greater discharge than expansion under equilibrium conditions.

In the preceding discussion two possibilities have been suggested; the equilibrium expansion followed path BCD and the expansion with undercooling followed the path BEF. The question now arises: which of these paths is taken in the actual flow through a nozzle? One is naturally inclined at first to the hypothesis of equilibrium expansion; but when one reflects over the matter, the expansion with undercooling appears to be the normal process. A change of state with equilibrium constantly maintained is an ideal process which is never realized, and which if realized would require infinite time. Equilibrium indicates a static, dead condition. Any movement from an equilibrium state must be preceded by a disturbance of equilibrium, and the more rapid the change, the greater is the departure from equilibrium. In the case of the flow of steam through a nozzle the time is measured in thousandths or ten-thousandths of a second; therefore a wide divergence from the ideal equilibrium expansion would be expected.

Direct evidence of supersaturation is furnished by the experiments of Wilson and Stodola. These show conclusively that the rapid adiabatic expansion of dry, or slightly superheated, steam is *not* accompanied by immediate condensation. The steam is undercooled and there is no evidence of the formation of mist until the degree of supersaturation has attained a considerable magnitude.

Indirect evidence of supersaturation is given by the fact that the coefficient of discharge is greater than 1 in certain cases. As shown in the preceding example, if the discharge is calculated from the conditions that apply to equilibrium expansion, the actual discharge with undercooling may be 3 or 4 per cent greater.

The calculations of the conditions of flow through a nozzle, taking account of supersaturation, require a knowledge of the properties of undercooled steam. A complete exposition of the thermodynamics underlying supersaturation lies beyond the scope of this paper; however, it is necessary to present as simply as possible certain important deductions.

After a certain degree of supersaturation, condensation appears in the form of a mist of small drops. The formation of these drops is promoted by the presence of nuclei, as particles of dust. If such nuclei are not

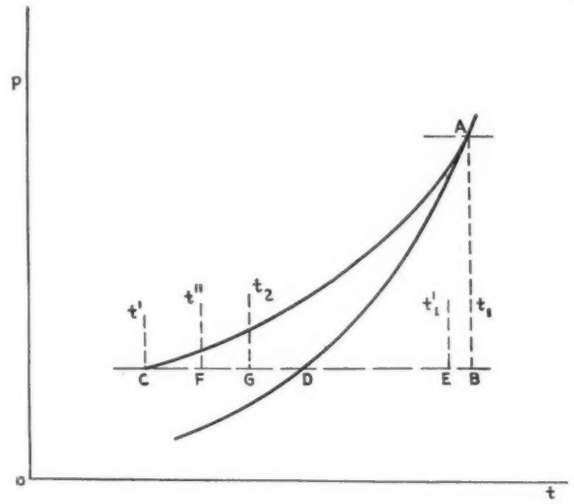


Fig. 5—Pressure-temperature diagram showing sudden expansion of wet steam

present, a considerable degree of supersaturation must be attained before condensation starts. Wilson's experiments indicated a ratio $p/p_s = 8$; Stodola's experiments, at a higher temperature and pressure, gave a ratio 3.1 to 3.3. Applying the Kelvin-Helmholtz formula (see the following paragraph) it is found that the two sets of experiments agree in giving the same radius of the water drop—about 2×10^{-8} ft. (5 ten-millionths of an inch diameter). These experiments indicate, therefore, that the lower limit of supersaturation is reached when the conditions are such as to require this radius of drop, when condensation starts.

The drop of water exhibits the phenomenon of surface tension. The surface layer of molecules, because of attractive forces, acts like an elastic membrane enclosing the drop. Because of the surface tension, the pressure inside the drop is held in equilibrium by the pressure of the steam atmosphere outside and the surface tension around a circumference. From such considerations it is possible to deduce the following relation between the radius of the water drop and the degree of supersaturation. This is the Kelvin-Helmholtz formula

$$\log_e \frac{p}{p_s} = \frac{2\sigma}{D_o r R T}$$

In this formula the ratio $\frac{p}{p_s}$ is the degree of supersaturation already defined; σ denotes the surface tension of water (lb. per ft.), D_o the density of water (lb. per

cu.ft.), r the radius of the water particle (ft.), T the absolute temperature (deg. F.), and R the gas constant in the formula $pv = RT$ applied to steam. To give an idea of the numerical magnitudes involved, the following results are obtained with $T = 700$.

$$r = 10^{-9} \quad 10^{-8} \quad 10^{-7} \quad 10^{-6} \quad 10^{-5} \text{ ft.}$$

$$\frac{p}{p_s} = 8.15 \quad 1.23 \quad 1.021 \quad 1.0021 \quad 1.0002$$

It is seen that if the radius of the drop is 10^{-5} ft. or larger, the ratio $p:p_s$ is very nearly 1 and the undercooling is insignificant. On the other hand, if the ratio $p:p_s$ is of the order 2 to 8, the radius of the drop is between 10^{-8} and 10^{-9} ft.

Because of the surface tension, a drop possesses a certain amount of energy analogous to the potential energy stored in a stretched membrane. This is called the *capillary energy* of the water. The surface tension of water is a linear function of the temperature.

$$\sigma = a - bT$$

and it may be shown that the capillary energy of a unit weight of water in the form of fine drops is given by

$$u_k = \frac{3a}{778 D_w r}$$

or with the proper constant inserted.

$$u_k = \frac{4.82 \cdot 10^{-7}}{r} \text{ B.t.u.}$$

When water is evaporated energy must be supplied for the disgregation work of breaking up the molecular structure. This energy comes from the surroundings and is stored as potential energy in the steam. Conversely, upon the condensation of steam the potential energy is given up. Part of this energy is absorbed by the surrounding steam atmosphere, the temperature of which is thereby increased. If the condensation is in the form of small drops part of the potential energy must be transformed into capillary energy of the drops.

Referring to Fig. 1, point N represents the state of undercooled steam without water; points between N and B represent undercooled steam with some condensation. A point near N indicates steam considerably undercooled, with drops of small radius having a considerable amount of capillary energy. A point nearer B indicates less undercooling, larger drops, and a smaller amount of capillary energy. Finally point B represents the equilibrium state with no undercooling and no capillary energy.

The total heat of a unit weight of undercooled steam at pressure p and temperature t is found by substituting these values of p and t in the usual formula for the total heat of superheated steam. In the same way the specific volume v and entropy s are obtained. The properties of undercooled steam may be calculated and tabulated just as are the properties of superheated steam. The table gives values for $p = 20$ lb. per sq.in. computed by Lawrence Bowditch.

The properties of a mixture of undercooled steam and water in the form of small drops may be found without difficulty. Let x denote the fraction of the mixture that is steam and y the fraction that is water, so that $x + y = 1$. As usual, let i' denote the heat of the liquid. Then the total heat of the water is $y\ (i' + u_k)$ and that of the steam is xi'', where i'' denotes the total heat of the undercooled steam. The total heat of the mixture is therefore

$$i = xi'' + y\ (i' + u_k)$$

As an example, let $p = 20$ lb., $t = 190$ deg., which corresponds to an undercooling of 38 deg. Then $i'' = 1138.8$, $i' = 157.9$, $u_k = 148.7$. For $x = 0.99$, $y = 0.01$, the total heat of the mixture is $i = 1{,}138.8 \times 0.99 + 0.01\ (157.9 + 148.7) = 1{,}130$ B.t.u. The volume of the mixture per pound is

$$v = xv'' = 0.99 \times 18.88 = 18.69 \text{ cu.ft.}$$

It has been assumed so far that the expanding steam was initially dry or superheated. Steam initially wet will likewise be supersaturated as the result of rapid expansion, though there is evidence that the undercooling is less the greater the amount of water present.

The water carried by the steam is in the form of drops the diameters of which depend some what on the steam velocity. Compared with the particles that are formed when condensation ensues after undercooling, these drops are large; that is, the diameter may be of the order 10^{-3} or 10^{-4} ft. instead of 10^{-7} or 10^{-8} ft. As a result of the sudden drop of pressure form p_1 to p_2, the equilibrium between the drop and the surrounding atmosphere of steam is disturbed. The following phenomena occur more or less simultaneously, but for the sake of clearness they are taken in sequence.

1. The point A, Fig. 5, represents the state of the mixture at the initial pressure p_1 and temperature t_1. The pressure drops suddenly to p_2. The drop of water retains its initial temperature t_1, therefore point B represents the new state of the water. The steam at the same time follows the path AC and at pressure p_2 shows an undercooling represented by CD.

2. The temperature of the drop is higher than the temperature of the surrounding atmosphere of steam,

PROPERTIES OF SUPER-SATURATED STEAM AT 20 LB. PER SQ. IN. ABS.

Temp.	Volume v''	Entropy s''	Total Heat i''	Capillary Energy u_k	Ratio $p:p_1$
220	19.85	1.7286	1153.8	32.2	1.163
210	19.53	1.7212	1148.8	71.9	1.416
200	19.20	1.7136	1143.8	110.6	1.735
190	18.88	1.7059	1138.8	148.7	2.141
180	18.55	1.6980	1133.7	186.0	2.663
170	18.22	1.6899	1128.5	222.7	3.339

hence the drop sends out molecules that have a higher mean speed than the speed of the steam particles. The temperature of the drop falls as a result of the evaporation from the surface, and the state point moves from B to E. At the same time the temperature of the steam is raised from t' to t'' so that the point representing the state of the undercooled steam moves from C to F.

The heat required for the evaporation at the surface of the drop is conducted from the interior of the drop. The time of the whole process is so short (0.001 sec. or less) that it would appear that the heat thus transferred would be inappreciable. However, the diameter of the drop is correspondingly small so that the flow of heat even in the short time available may be sufficient to show an appreciable effect. At any rate, experiments show that the more water in the initial mixture the smaller the undercooling; a result that would be expected if this second phenomenon has any influence.

3. Condensation may start in the undercooled steam, but the large drops of water initially in the steam are hotter than the surrounding undercooled steam and cannot serve as nuclei for condensation. Consequently the condensation must take the form of a mist of particles having diameters dependent on the degree of supersaturation. As a result of this condensation, the temperature of the whole mass of steam will rise from t'' to t_2, and the point G will represent the state of the vapor part of the mixture.

Table I—Prime Movers, Motors and Generators in American Manufacturing Plants by

(United States Census of

Division and State	Number of Establishments Reporting Power	Prime Movers								
		Total Primary Horsepower	Steam Engines		Steam Turbines		Internal-Combustion Engines		Waterwheels and Water Turbines	
			Number	Horsepower	Number	Horsepower	Number	Horsepower	Number	Horsepower
United States:										
1925	167,649	35,772,628	74,691	11,434,388	7,485	5,482,468	14,362	1,186,116	8,393	1,800,828
1923	172,754	33,056,870	*90,019	*16,697,573	*	*	15,696	1,223,297	9,289	1,803,220
1919	222,253	29,297,963	116,017	13,834,016	6,438	3,197,599	30,437	1,240,868	13,976	1,765,031
Geographic Divisions:										
New England	16,628	4,349,191	5,862	1,080,002	949	720,265	694	38,866	3,222	777,472
Middle Atlantic	51,046	10,106,390	18,168	3,464,339	2,172	1,571,307	3,553	347,197	2,174	325,962
East North Central	38,324	10,047,780	16,825	3,014,432	2,093	1,748,513	3,083	395,788	1,330	245,364
West North Central	14,815	1,855,278	4,922	553,291	447	239,290	1,271	81,520	268	65,525
South Atlantic	15,159	3,454,150	10,516	1,073,426	590	393,842	2,121	150,250	887	292,285
East South Central	7,661	1,615,183	6,153	718,751	281	194,595	1,250	31,159	145	16,934
West South Central	7,284	1,316,933	5,684	652,730	334	203,829	1,276	93,453	31	2,837
Mountain	3,460	757,974	1,698	273,964	155	122,565	296	12,444	89	6,274
Pacific	13,272	2,269,749	4,863	603,453	464	288,262	898	35,439	247	68,175
New England:										
Maine	1,387	600,787	855	104,840	80	51,969	101	2,386	763	301,532
New Hampshire	986	370,740	543	78,881	56	79,615	81	2,765	510	162,183
Vermont	889	178,806	381	37,925	19	10,288	42	1,667	321	59,153
Massachusetts	9,052	2,013,017	2,652	563,017	455	372,808	295	11,545	1,020	176,934
Rhode Island	1,452	395,754	422	97,688	118	86,880	22	2,195	162	21,363
Connecticut	2,863	790,087	1,009	197,651	221	118,705	153	18,308	446	56,307
Middle Atlantic:										
New York	28,329	3,348,184	5,545	768,540	675	370,660	1,179	72,111	1,303	293,847
New Jersey	7,332	3,384,234	2,982	465,824	483	328,247	591	34,918	183	8,714
Pennsylvania	15,385	5,373,972	9,641	2,229,975	1,014	872,400	1,783	240,168	688	23,401
East North Central:										
Ohio	10,205	3,482,618	4,568	1,139,069	716	623,083	1,006	133,218	173	8,065
Indiana	4,429	1,420,989	2,399	311,718	209	293,261	339	163,210	132	7,802
Illinois	12,265	2,247,408	3,908	778,972	651	304,454	507	77,758	110	9,872
Michigan	5,205	1,187,750	2,508	438,353	335	438,862	323	8,959	266	40,138
Wisconsin	6,220	1,009,015	3,442	348,320	182	89,753	908	12,643	649	179,487
West North Central:										
Minnesota	3,519	508,821	1,388	133,336	128	90,220	203	20,510	110	55,908
Iowa	3,012	308,016	845	88,641	76	47,988	222	5,590	28	1,072
Missouri	4,571	590,485	1,609	194,208	109	33,965	357	18,397	38	986
North Dakota	301	16,711	80	4,544	11	5,463	153	1,826	10	85
South Dakota	458	21,463	117	6,559	7	2,650	48	986	6	293
Nebraska	1,203	133,708	274	46,901	44	14,451	133	4,935	34	2,382
Kansas	1,751	276,874	609	79,102	72	44,553	255	29,276	32	4,799
South Atlantic:										
Delaware	392	107,391	406	38,821	31	26,254	45	1,245	45	2,383
Maryland	2,808	544,558	1,598	109,473	134	65,165	329	79,892	67	4,690
District of Columbia	416	37,508	71	7,816	19	2,909	31	544	3	895
Virginia	2,396	441,807	1,685	139,401	90	73,768	215	9,657	334	34,070
West Virginia	1,295	431,981	901	158,766	66	79,854	324	32,174	38	8,295
North Carolina	2,545	800,051	1,928	202,569	86	46,419	181	6,958	225	175,517
South Carolina	1,088	423,359	988	153,593	54	37,779	74	1,992	84	39,061
Georgia	2,621	523,334	1,990	182,951	75	55,593	509	6,121	89	27,363
Florida	1,598	144,161	949	80,036	35	6,101	413	11,667	2	11
East South Central:										
Kentucky	1,734	257,965	873	91,957	35	18,941	226	6,564	34	1,852
Tennessee	2,031	447,529	1,532	170,958	89	60,855	139	5,091	97	3,870
Alabama	2,233	697,998	2,152	308,136	124	85,936	441	8,238	14	11,212
Mississippi	1,663	211,691	1,596	107,700	33	28,863	444	11,266	.....	.....
West South Central:										
Arkansas	1,207	177,011	1,256	117,600	39	20,020	161	8,188	6	76
Louisiana	1,609	410,298	2,178	282,735	117	50,882	283	18,480	7	125
Oklahoma	1,175	156,826	527	54,600	31	31,502	280	19,268	1	30
Texas	3,293	572,798	1,723	207,795	147	101,425	552	47,517	17	2,606
Mountain:										
Montana	540	166,528	217	29,224	8	3,650	46	1,078	4	2,350
Idaho	437	82,552	287	41,639	21	15,328	32	604	24	683
Wyoming	206	28,721	93	9,357	29	7,653	54	1,927	4	107
Colorado	1,252	219,865	589	109,434	44	17,417	80	1,405	13	662
New Mexico	190	18,842	102	12,968	7	1,718	22	1,271	.....	.....
Arizona	267	102,127	139	28,801	31	51,061	30	2,814	.....	.....
Utah	475	124,735	243	39,154	11	25,558	20	443	40	1,877
Nevada	93	14,604	28	3,387	4	180	12	2,912	4	595
Pacific:										
Washington	2,956	748,110	2,410	326,865	120	143,143	241	6,414	54	10,163
Oregon	1,734	387,749	1,057	135,933	46	57,406	148	6,782	129	50,087
California	8,582	1,133,890	1,396	140,655	298	87,713	429	22,243	64	7,925

*Steam turbines included with steam engines.

Table II—Prime Movers, Motors and Generators in American Manufacturing Plants by

Group and Industry	Number of Establishments Reporting Power	Prime Movers								
		Total Primary Horsepower	Steam Engines		Steam Turbines		Internal-Combustion Engines		Waterwheels and Water Turbines	
			Number	Horsepower	Number	Horsepower	Number	Horsepower	Number	Horsepower
All industries, total	167,649	35,772,628	74,691	11,434,388	7,485	5,482,468	14,362	1,186,116	8,393	1,800,828
Industrial Groups										
Food and kindred products	43,180	3,881,952	16,035	1,417,989	642	242,342	4,661	177,417	2,126	109,392
Textiles and their products	22,372	3,986,136	4,249	1,101,373	752	755,822	336	19,067	2,054	460,951
Iron and steel and their products, not including machinery	5,923	7,518,999	6,158	3,035,612	1,183	1,428,871	754	599,456	211	19,050
Lumber and allied products	20,623	3,472,770	21,065	2,088,709	640	404,891	2,652	57,959	749	48,448
Leather and its manufactures	3,901	413,759	1,144	158,004	74	54,099	82	4,434	79	4,955
Rubber products	462	656,857	345	82,487	108	145,617	14	294	25	3,241
Paper, printing and related industries	23,305	3,060,794	3,182	672,942	601	422,689	721	12,020	2,255	934,372
Chemicals and allied products	7,354	2,984,913	10,621	948,151	2,242	681,773	1,036	79,468	117	154,596
Stone, clay and glass products	7,915	2,348,157	3,961	571,508	288	366,406	1,753	111,836	163	29,096
Metal and metal products, other than iron and steel	5,500	1,158,486	940	236,573	170	194,627	240	20,947	21	7,299
Tobacco manufacturers	732	42,075	142	21,038	12	4,100	11	73	6	207
Machinery, not including transportation equipment	11,482	2,714,377	2,225	377,454	314	355,738	1,098	63,762	395	22,166
Musical instruments and phonographs	421	97,318	174	34,434	24	23,255	19	748	4	220
Transportation equipment, air, land and water	2,722	1,888,961	1,214	271,920	220	308,773	354	16,766	31	1,487
Railroad repair shops	2,035	942,248	1,898	286,340	164	66,264	147	4,823	3	32
Miscellaneous industries	9,722	604,826	1,338	129,854	51	27,201	484	17,045	104	5,316

States—January 1, 1926

Manufactures)

Electric Motors By Purchased Energy		Electric Motors Driven by Current Generated in Establishment Reporting		Electric Generators	
Number	Horsepower	Number	Horsepower	Number	Kilowatts
1,724,180	15,868,828	772,445	10,254,745	23,635	6,887,445
1,438,737	13,332,780	616,020	8,819,217	.....	.....
972,062	9,260,449	486,130	6,965,174	.....	.....
209,547	1,732,586	120,546	1,234,115	3,197	992,470
522,179	4,397,585	250,689	3,128,254	6,517	1,992,423
501,924	4,643,683	263,698	3,520,410	7,630	2,136,254
106,039	915,652	33,827	501,012	1,413	346,150
157,878	1,544,347	52,044	777,182	1,924	586,451
50 580	653,744	12,618	201,001	777	213,418
37,050	364,084	13,491	287 961	1,119	235,634
24,200	342,727	6,347	137,475	364	120,147
114,783	1,274,420	19,185	467,335	694	264,098
11,667	140,060	7,999	150,991	316	131,143
6,126	47,296	12,793	181,647	278	143,582
6,010	69,773	2,605	32,730	116	28,928
117,239	888,713	61,429	577,135	1,428	429,406
25,159	187,628	12,662	101,550	340	92,507
43,536	399,116	22,878	190,062	719	166,904
240,037	1,843,026	75,666	710,377	2,084	508,905
72,312	546,531	53,022	511,347	1,381	422,123
209,830	2,008,028	122,001	1,906,530	3,052	1,061,395
146,574	1,581,183	58,378	1,151,619	1,727	632,580
62,590	645,898	32,732	633,770	674	342,715
130,941	1,076,352	59,901	724,385	1,559	431,721
113,487	961,438	76,424	650,578	2,804	499,739
48,332	378,812	36,253	360,058	866	229,499
23,985	208,047	8,636	154,518	318	119,136
20,052	164,725	6,537	84,503	243	58,556
40,300	342,929	12,826	144,113	489	85,438
1,296	4,793	316	5,072	25	4,058
2,046	10,975	82	3,949	9	2 405
7,848	65,039	1,856	31,908	94	19,563
10,512	119,144	3,574	76,949	235	56,994
2,857	38,688	2,701	40,553	79	27,497
24,909	285 338	6,462	213,117	219	89,438
3,507	25,344	162	2,387	22	2,078
16,086	184,911	17,123	129,470	402	98,317
11,401	152,892	6,461	156,339	342	123,889
49,833	368,588	8,611	82,037	297	97,259
20,530	190,934	5,908	77,140	201	66,776
22,150	251,306	3,916	62,986	254	67,589
6,605	46,346	700	13,153	108	13,608
11, 968	138 651	4 437	43 913	188	32 306
18,616	206,755	4,121	60,440	256	67,551
17,359	284,476	3,026	66,697	187	81,226
2,636	23,862	1,034	29,951	146	32,335
3,527	31,137	1,697	28,983	152	23,588
7,138	68,076	3,463	85,776	363	77,031
6 102	51,426	1,928	46,991	150	32,150
20,283	213,455	6,403	126,211	454	102,868
4,566	130,226	432	12,808	33	5,199
2,174	24,298	578	18,294	47	14,842
1,057	9,677	374	9,773	32	6,433
8,388	90,947	2,008	34,860	112	28,094
485	2,885	381	6,237	21	3,833
1,441	19,451	1,561	39,428	44	43 405
5,498	57,713	852	16,281	52	15,150
591	7,530	161	2,794	23	3,141
18,634	267,525	7,489	250,017	287	133,539
11,351	137,541	3,861	91,736	132	59,472
84,798	875,354	7,835	125,582	275	71,087

Groups of Industries

Electric Motors Driven By Purchased Current		Electric Motors Driven By Energy Generated in Establishment Reporting		Electric Generators	
Number	Horsepower	Number	Horsepower	Number	Kilowatts—
1,724,180	15,868,828	772,445	10,254,745	23,635	6,887,045
215,059	1,934,812	61,694	630,451	3,539	462,238
317,906	1,648,922	149,965	1,042,363	2,884	993,955
138,507	2,436,010	109,121	2,953,810	2,051	1,450,275
100,339	872,763	54,520	836,036	2,544	576,277
41,412	192,267	18,731	133,028	638	114,424
21,793	425,218	11,941	193,484	207	132,713
234,012	1,018,771	41,716	884,872	1,833	679,365
72,549	1,120,925	48,093	771,057	2,010	608,894
57,654	1,269,311	25,460	624,131	1,380	463,414
56,766	699,040	18,597	263,936	587	253,993
6,141	16,657	3,162	14,974	85	14,978
216,843	1,895,257	120,150	927,720	2,019	526,716
7,148	38,661	5,676	49,522	127	28,527
132,521	1,290,015	74,642	593,851	2,474	379 983
36,495	584,789	16,748	260,938	882	142,451
69,035	425,410	12,229	74,572	375	58,842

Electric Generators in Private Plants Total 6,887,045 Kw.

POWER is glad to be able to make available to its readers these preliminary results of the most recent studies of the Bureau of the Census, as secured for *Power* by R. M. Davis, Statistician of the McGraw-Hill Publishing Company.

ACCORDING to a United States Census of Manufactures report just issued, there were on Jan. 1, 1926, a total of 167,649 manufacturing establishments in the nation using power. This shows a decrease of 5,105, or 3 per cent from Jan. 1, 1924, two years previous. The installed primary power of these plants on Jan. 1, 1926, totaled 35,772,628 hp., a gain of 2,715,758 hp., or 8.2 per cent, during the two years since the previous census was taken. Of the various types of prime movers in use, steam engines lead, with a reported installation of 11,434,388 hp. a decrease of 2,399,628 hp., or 17.4 per cent during the five-year period 1920-26. On the other hand, the installation of steam turbines showed an increase of 2,284,869 hp., or 71.7 per cent during the same period. Both internal-combustion engines and waterwheels showed a decrease from 1924 to 1926, but the installation of electric motors run by purchased energy showed a gain of 2,536,048 hp., or 19 per cent, during the same two-year period. The number of motors installed in manufacturing plants on Jan. 1, 1926, totaled 2,500,625 with a combined rating of 26,123,573 hp. This is an increase of 445,868 motors and an increase in installed motor rating of 3,971,576 hp., or 18 per cent since Jan. 1, 1924. During the two-year period the rating of motors run by privately generated energy increased by 1,435,528 hp., or 16.3 per cent, while the rating of motors run by purchased energy increased by 2,536,048 hp., or 19 per cent.

Much interesting material can be dug out of this tabulation. For instance, if from the total 35,772,628 hp. of prime movers one subtracts the 15,868,828 covering electric motors driven by purchased energy, the remainder, 19,903,800, is the total rating of mechanical prime movers. If from this one subtracts the 10,254,745 hp. of motors driven by home-generated energy, the remainder, 9,649,055 is perhaps a fair estimate of the capacity of mechanical prime movers—steam and internal-combustion and hydraulic—that is transmitted to the load by mechanical transmission rather than electric. On these total figures it appears that about 48 per cent of the energy generated by engines and waterwheels is transmitted mechanically. A study of the individual industries listed indicates that this fraction varies from 27 to 68 per cent. Comparison with previous years shows that the figure has been decreasing somewhat, but in many instances there seems to be a continuing field for mechanical transmission equipment, at least for years to come.

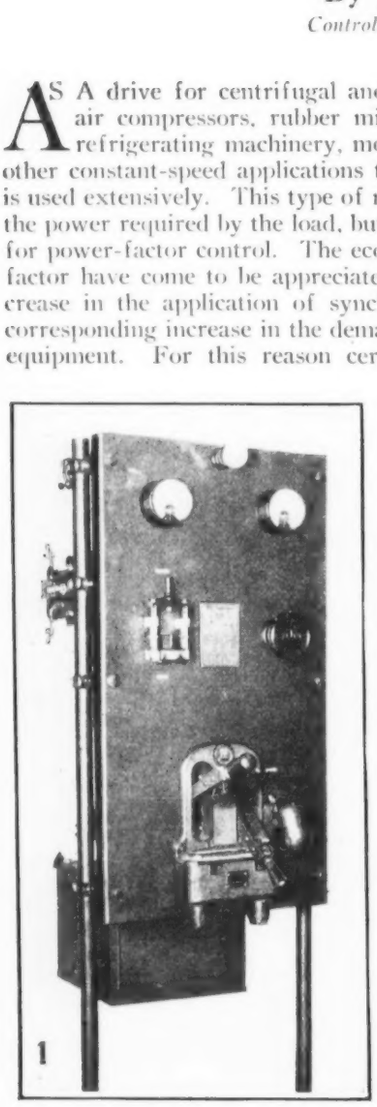
Controllers for Starting Synchronous Motors

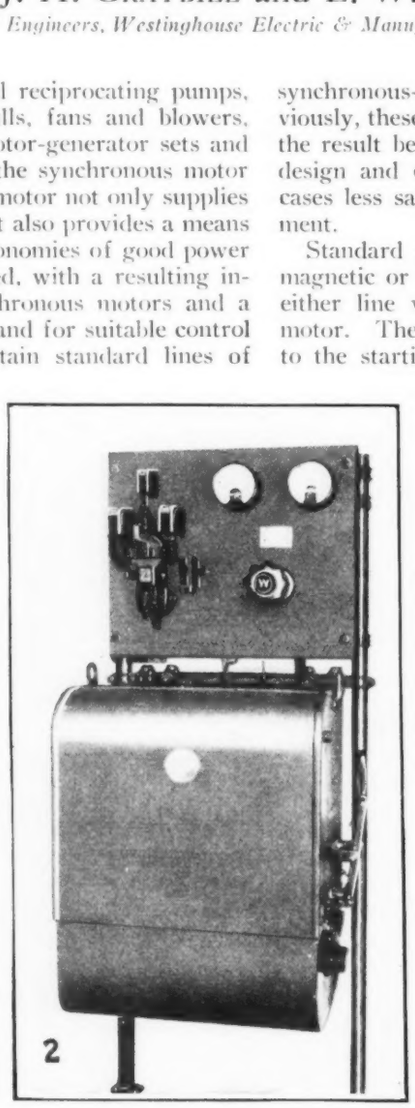
Types of Starters That Have Become Standard for Synchronous Motors and the Kind of Protection for These Motors

By J. H. GRAYBILL and E. W. DEVEBER
Control Engineers, Westinghouse Electric & Manufacturing Company

AS A drive for centrifugal and reciprocating pumps, air compressors, rubber mills, fans and blowers, refrigerating machinery, motor-generator sets and other constant-speed applications the synchronous motor is used extensively. This type of motor not only supplies the power required by the load, but also provides a means for power-factor control. The economies of good power factor have come to be appreciated, with a resulting increase in the application of synchronous motors and a corresponding increase in the demand for suitable control equipment. For this reason certain standard lines of synchronous-motor starters have been developed. Previously, these starters were designed and built as ordered, the result being that successive orders were of different design and consequently more expensive, and in some cases less satisfactory, than the present standard equipment.

Standard starters may be classified as either manual, magnetic or semi-magnetic in operation and provide for either line voltage or reduced voltage starting of the motor. The line-voltage starters are commonly applied to the starting of low-speed motors, while the higher-





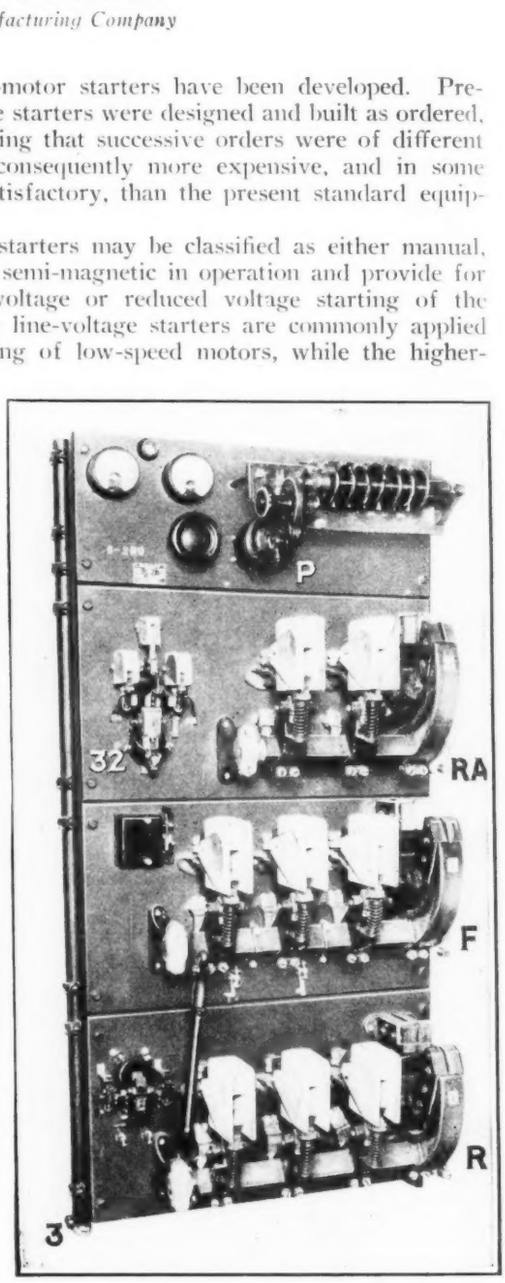


Fig. 1—Reduced-voltage manual starter with double-throw oil switch
Fig. 2—Reduced-voltage semi-magnetic starter
Fig. 3—Full-magnetic reduced-voltage starter

speed motors ordinarily require some form of reduced-voltage starter.

A typical manually operated reduced-voltage starter for a synchronous motor is shown in Fig. 1. The motor is connected to the taps of the auto-transformer by the operator moving the start handle of the double-throw circuit breaker to the closed position. When the motor has reached approximate synchronous speed, as determined by the operator observing the slow frequency oscillation of the field ammeter, the start handle of the circuit breaker is released and the run handle moved to the closed position, thus placing the motor on full voltage. With the motor operating at this speed on full voltage, the operator closes the field switch. Exciting the fields provides torque to pull the motor into synchronism.

Semi-Magnetic Type Starter

The semi-magnetic starter shown in Fig. 2 is likewise manually operated with regard to the method of applying alternating current to the motor, but has the advantage of having the field voltage applied by the automatic field contactor. The motor is started by the operator moving the auto-starter handle to the start position and at the proper time moving this handle to the run position. This part of the starting operation having been accomplished by the operator, the automatic field contactor accomplishes the remainder by exciting the field winding when the motor has accelerated to the proper speed.

The voltage induced in the field winding of a synchronous motor is a maximum at start, at which time the rotor is at rest, and the frequency of the induced voltage at this time is equal to that of the alternating-current supply. As the motor increases in speed, the

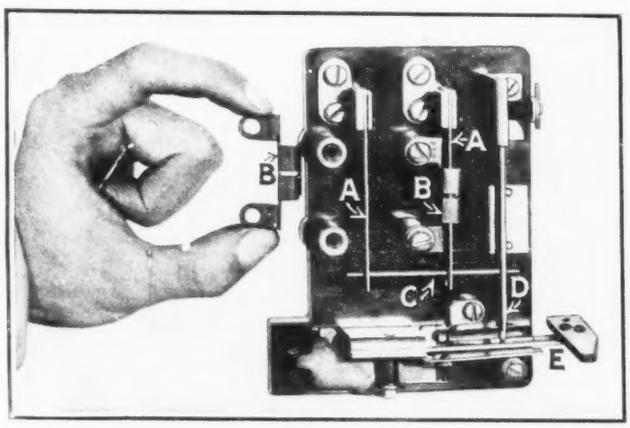


Fig. 4—Thermal overload relay showing heater removed from one pole

induced voltage decreases, but the frequency, and consequently the impedance, decreases in like proportion. The induced current in the field winding therefore, since the voltage and impedance vary in approximately like proportion, remains approximately constant until the motor has accelerated to almost synchronous speed, at which time this current abruptly decreases.

The tendency of the induced field current to remain constant almost to synchronous speed has been made use of in the design of the automatic field contactor. This contactor consists of a double magnet with two poles up and one down. The upper contacts serve, when closed, to connect the field across the direct-current supply, while the lower contacts normally keep the field shorted through the starting and discharge resistor. The lower contacts are normally closed by gravity and in addition, during the starting period, are held closed by the lower coil being connected in series with the motor field. Opposed to the action of this coil, and tending to close the

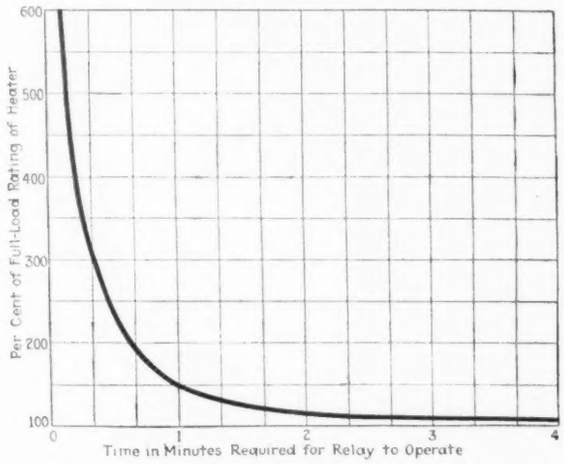


Fig. 5—Calibration curve of thermal overload relay

upper contacts, is a shunt coil which is connected across the direct-current supply. These coils are so proportioned that the upper contacts will not close until the induced field current has reached a low value.

In Fig. 4 is shown a two-pole thermal overload relay with which the magnetic starters are equipped. Each pole of the relay consists of a bi-metal strip *A* and its heating element *B*. The bi-metal strip is made of two metals of different coefficients of expansion. When this strip is heated, it assumes a curved position, because of one metal expanding more than the other, and in so doing moves the push rod *C* and trip lever *D* toward the opening in the contact lever *E*. The stationary and moving contacts are held together against the action of a spring by the pressure of the end of the trip lever against the contact lever.

In event the bi-metal strips have heated sufficiently to move the push rod and trip lever to such a position that the end of the trip lever coincides with the opening in the contact lever the pressure holding the contacts together is released and the action of the spring separates the stationary and moving contacts, in this way tripping the relay. Each of the two bi-metal strips acts independently and either or both may act to trip the relay.

Calibration of Overload Relays

The heaters are connected in the motor leads either directly or through current transformers. They are designed so as to convey enough heat to the bi-metal strips to trip the relay in approximately twenty minutes when the current corresponds to the normal heater rating and the calibration lever is set on 100 per cent. In Fig. 5 is shown a typical curve giving the relation between current in percentage of normal heater rating and the corresponding time required for the relay to operate.

Being a thermal device and subjected to the same

current as the motor with which it is used, the operating characteristics of this relay are directly in proportion to the heating in the motor windings and afford ideal protection to the motor.

In order to adapt this relay to the protection of a particular motor it is only necessary to apply heaters based upon the full-load motor current. Heaters are ordinarily provided whose current rating is approximately 115 per cent of that of the motor. By means of a calibration lever the setting may be changed as desired between 80 and 120 per cent of the heater's normal rating, which is equivalent, since the heater rating is 115

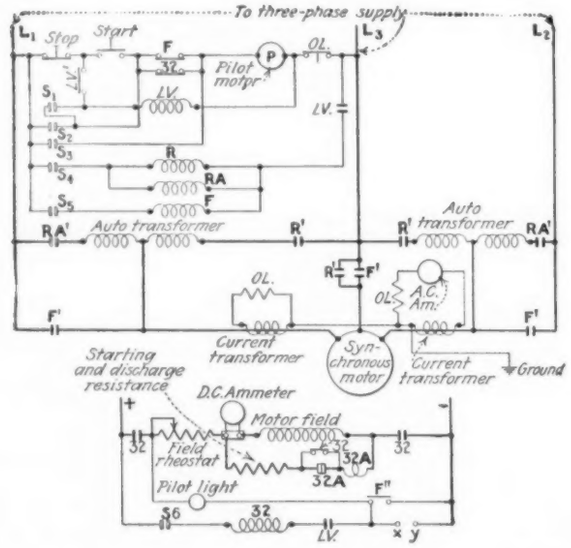


Fig. 6—Simplified diagram of reduced-voltage full-magnetic starter

per cent of that of the motor, to settings between 92 and 138 per cent of the motor rating.

The operation of the full-magnetic reduced-voltage starter is controlled by a push-button station and requires no other attention from the operator during the starting period. By reference to the starter, Fig. 3, and the simplified wiring diagram, Fig. 6, the function of the starter may be understood. Pressing the start button, energizes the pilot-motor P causing rotation of the cam switch to such a position that contact S_1 is closed. The closing of this contact energizes the low-voltage relay coil LV' and completes the interlocking circuit around the start button which is through the low-voltage relay interlock LV'' and contact S_1 to the pilot motor. The operation of the starter from this time is entirely automatic. The cam switch continues the starting operation by closing cam contact S_4. This energizes the operating coils of the reduced voltage contactors R and RA and places the motor on reduced voltage through the taps of the auto transformer, by closing contacts R' and RA'.

After the time interval has elapsed for which the cam switch has been provided, contact S_4 opens and releases the reduced-voltage contactors, and S_5 closes. The closing of S_5 energizes the operating coil F of the full-voltage contactor and places the motor directly across the line, by closing contacts F'. Closing the full-voltage contactor also closes the F'' interlock in the field-contactor circuit, and permits the shunt coil of this contactor to be energized and field voltage to be applied when the induced current in the other coil of this contactor has decreased to the proper value.

A short interval after the full-voltage contactor has closed, cam contact S_2 closes and contact S_3 opens. The opening of contact S_3 stops the pilot motor with the starter in the running position.

To stop the motor the operator presses the stop button. This operation releases the low-voltage relay LV and the opening of its contacts de-energizes both the field-contactor and line-contactor coils. These contactors are provided with interlocks which complete the pilot-motor circuit, through contact S_2, when these contactors open, in this way energizing the pilot motor, which turns the cam switch to the off position.

Kinds of Protection Used

In general, control equipment for synchronous motors should protect the motor against failure of the direct-current supply, failure of the alternating-current supply, overload, phase failure, and an open field circuit. In some cases it is also desirable to protect the motor against other undesirable conditions, such as abnormal heating of the bearings. However, protection against these latter conditions is generally not required and is therefore not provided on standard control equipment.

The standard magnetic reduced-voltage starter is provided with a field contactor interlock 32, Fig. 6, in series with the pilot motor, such that the pilot-motor circuit remains closed until 32 field contactor closes. The cam switch will therefore rotate to the off position if the direct-current coil of the automatic field contactor is de-energized and permits this contactor to open. This feature provides protection against failure of the direct-current supply, and consequently loss of field excitation, during either the starting or running periods.

The line contactor F is likewise provided with an interlock F in parallel with 32 of the field contactor, and which completes the pilot-motor circuit in a similar manner when the line contactor opens. However, with failure of the alternating-current supply, the pilot motor will not rotate the cam switch to the off position until power is again provided. In this case re-energizing of the line-voltage contactor coil, with the return of power, is prevented by the contacts LV of the low-voltage relay, which are in series with this coil and which also open when the power supply fails.

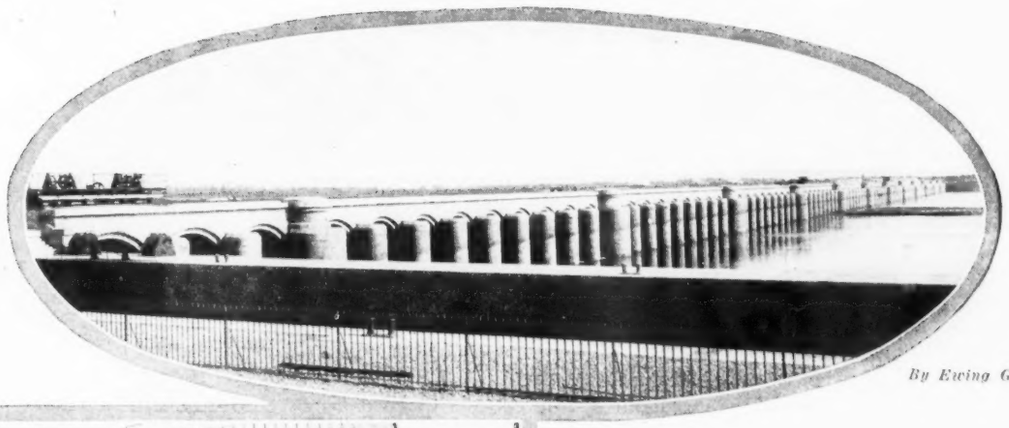
Motor Protected With Thermal Relays

The thermal overload relay, Fig. 4, is used on these starters and affords adequate protection to the motor with a minimum of interruptions. It affords overload protection during both the starting and running periods.

In case of phase failure and resulting single-phase operation, or an open field circuit, the motor will not be damaged unless the resulting increase in current is sufficient to cause overheating of the motor windings. The thermal overload relay is likewise affected by this increase in current, and with proper application, will remove the motor from the line before the temperatures become injurious.

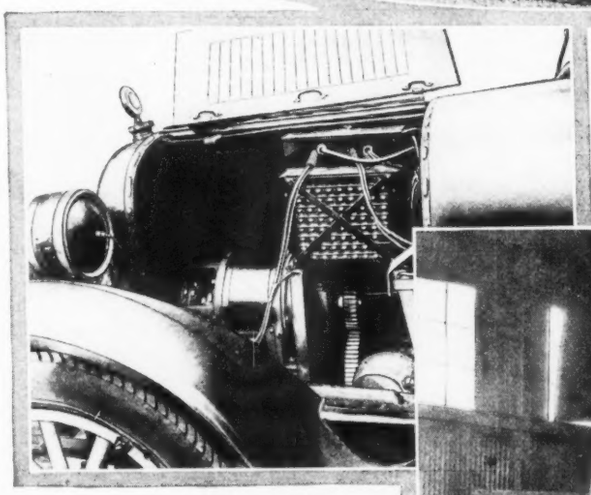
The line-voltage magnetic starter is similar to the reduced voltage type previously described, but is much simpler in operation because only a line contactor is required and a timing device is unnecessary. This starter is also controlled by a push button station.

POWERGRAPHS



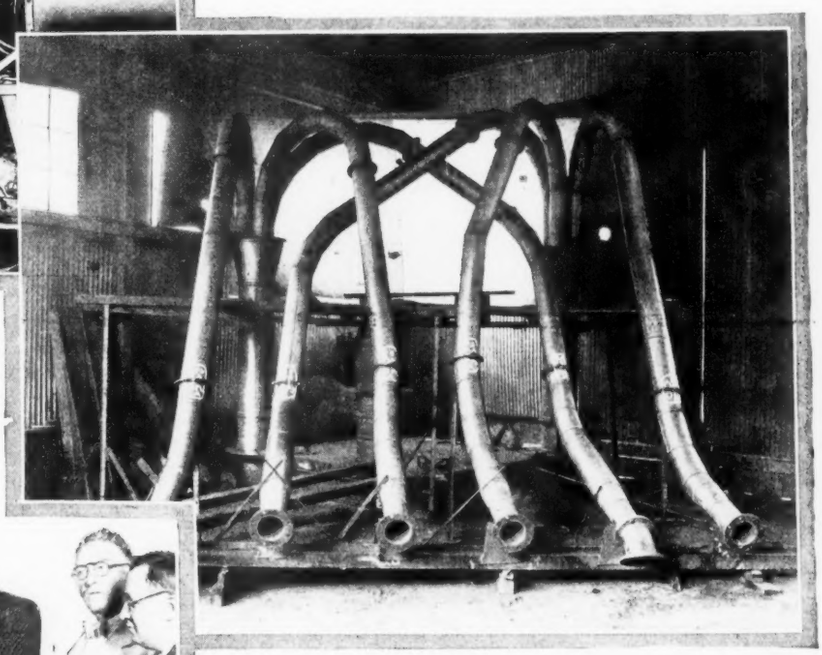
By Ewing Galloway

Above—Aswan Dam on the Nile, Egypt, as seen from the south. Power developed will operate railroads and stimulate growing industries of the region.

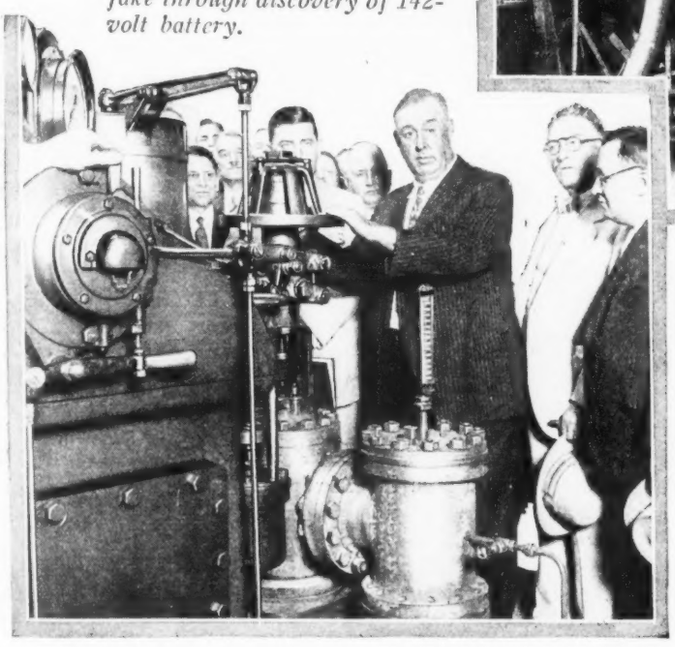


Wide World Photo.

"Air Driven Motor" for auto, above, claimed to harness electricity from air, proves fake through discovery of 142-volt battery.



Above—Some arc-welded pipe in course of manufacture, using lap-seam joints. The fitting-up bolts on the longitudinal seams are drawn, and the holes welded shut. Support brackets welded to pipe are seen.



Wide World Photo

At Left—Mayor Thompson of Chicago "opening" the pumping station of 300,000,000 gal. daily capacity. This station, named the William Hale Thompson Pumping Station, will supply water to South Chicago. Note hand on emergency trip.

Conductivity Methods of Measuring Condenser Leakage

By HENRY C. PARKER, *and* WILLARD N. GREER
Research Department, Leeds & Northrup Company, Philadelphia

IT HAS long been known that, in solutions that approach distilled water in dilution, any salts present may, without great error, be considered 100 per cent ionized. It follows that the concentration of salts in such solutions may be represented as a linear function of the conductance of the solution. Arrhenius[1] and numerous other investigators have shown that the true conductance of the salts in these solutions may be found by subtracting the conductance of the solvent alone (water correction) from that of the solution. The conductance of the solution therefore can be used as a method of analysis.

This principle was applied by Digby[2] for the determination of surface condenser leakage. In this measurement the condensate may be considered as the solution to be analyzed, the steam (without leakage) as the solvent, and the circulating water as the source of salt. Digby also established the linear relation between the conductance and the concentration of the condensate (expressed in percentage of circulating water), but neglected an actual measurement to obtain the water correction. His method, in brief, was to take a sample of laboratory distilled water (representing steam without leakage) and, by adding various percentages of circulating water, establish a curve from which the condenser leakage could be approximated as soon as the conductance of the condensate had been measured. His apparatus was crude and his measurements contained an appreciable source of error due to the use of direct current in his "Conductance Meter" or modified "Megger."

Caldwell[3] was one of the first to describe the use of an alternating current in this measurement. On account of the high currents used (maximum of 0.5 ampere), however, it is doubtful if any considerable reduction in polarization was secured by the use of alternating current. Caldwell used a non-removable cell with brass electrodes, one of which was grounded. The cell was placed in the condensate line. He apparently neglected the "water correction" as well as the changes in the condition of the circulating water.

In a previous article from this laboratory[4] there was described the first removable type conductivity cell designed to be installed directly in the condensate line. In addition, a method of calibration was also described. This consisted in measuring a sample of condensed steam (without leakage) to get the true "water correction," and then by adding various percentages of cooling water a curve was obtained from which the leakage could be read as soon as the condensate was measured. The use of a recording Wheatstone bridge equipped with an alternating-current galvanometer and eliminating, for the first time, the error from polarization, was also described. The cell had porcelain insulation with two platinum electrodes neither of which was grounded, this method being inherently superior to a grounded system.

IN AN accurate measurement of condenser leakage by conductivity measurements three quantities have to be determined—the conductance of the condensate, the conductance of a condensed steam sample and the "corrected" conductance of a one per cent solution of circulating water. The latter value may be calculated with sufficient accuracy from a measurement of the conductance of the circulating water. The conductance of the condensed steam samples may be plotted as a function of the load and approximate values of this quantity may be subsequently read from this curve.

No practical way of obtaining a sample of the condensed steam was suggested until Edwards[5] developed what was, in principle at least, one of the best methods. It consisted in tapping the turbine at one of the final stages (a convenient place was found just previous to the next to last row of blades where an open space occurred in the turbine housing), inserting a cooling coil in the line and collecting the sample in a flask. Another line led from the flask to the exhaust space of the turbine so that, although the flask was under a partial vacuum, pressure differential sufficient for the collection of the sample was obtained.

Edwards was not entirely successful in his application of the method which he had developed for obtaining a sample of steam free from leakage. In fact the authors have concluded, after making measurements with his apparatus (at the Springdale Station of the West Penn Power Co.), that Edwards probably never obtained a

[1] Bihang Schwed. Akad. *8*, No. 13 and No. 14, 1884.
[2] *The Electrician* (London), *65*, 646 (1910).
[3] *Power*, *54*, 217 (1921).
[4] Keeler, *Power*, *55*, 126 (1922).
[5] *Power*, *60*, 907 (1924).

sample of steam free from contamination. The fact that contamination was present was clearly proved when it was found that the conductance values of the condensed steam samples were running higher than these of the condensate giving, by calculation, a negative leakage. The first problem encountered, therefore, was the elimination of the various sources of contamination.

The Collection of a Condensed Steam Sample Free From Contamination and Leakage

In improving the Edwards method of collecting the steam sample, it was first noted that the tap into the housing of the turbine was made at the side rather than at the top of the turbine. Consequently, it was thought possible that drainage from the turbine wall might account for the difficulty. The principal source of contamination, however, appeared to come from the flask in which the sample was collected and also from the air that was drawn in when the flask was collected and also from the air that was drawn in when the flask was taken from the line. The remedy for this was met by designing, in co-operation with L. E. Hankison, of the West Penn Power Co., a cell that could be inserted in the line and left there while measurements were being taken. The steam sample flows through continuously and keeps the cell clean, while there can be no contamination from air, since the cell is under a vacuum. A photograph of the cell in position on the turbine is shown in Fig. 1 and a cross-section in Fig. 2.

In Fig. 2 *A* represents the next to last stage and *H* the exhaust space of the turbine. A length of metal tubing (preferably of block tin) leads to the cooling coil *C*. The electrodes are shown at *G* and the leads at *F*. *A* stopcock *E* is provided for releasing the vacuum when it is desired to remove the electrodes.

There is shown diagrammatically, in Fig. 3 an optional method of collecting the steam sample. This removes

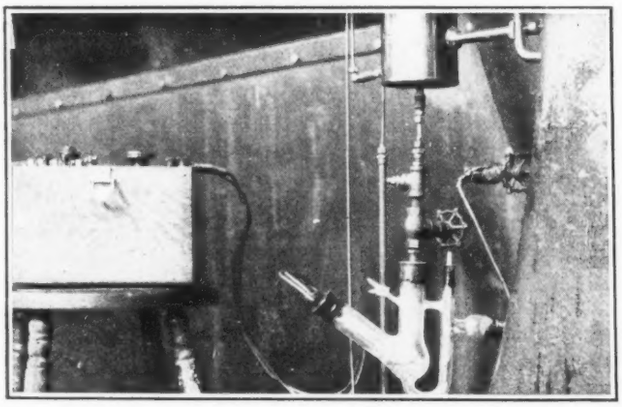


Fig. 1—The steam sampling cell installed

any objections to tapping the steam space of the turbine.[6] In this case the sample is drawn through a tin tube *D*, which extends a short distance into the neck of the condenser *A*. The tin tube leads to the block-tin cooling *E* and the steam cell *F*. A pipe runs from *F* to the bottom of the condenser. In order to obtain a sufficient pressure differential between these two taps, an aspirator *G* is inserted, operated by condensate from the hotwell pump *C*.

[6]This method was suggested to the writers by S. A. Curry.

In a permanent installation the steam cell is protected by a metal or wooden housing. Steam may be left running through the cell continually without impairing the efficiency or affecting the operation of the condensing unit. The cell is made of Pyrex glass, and it is evident, from the extremely high purity of the steam samples, that this is one of the few materials that could be used in

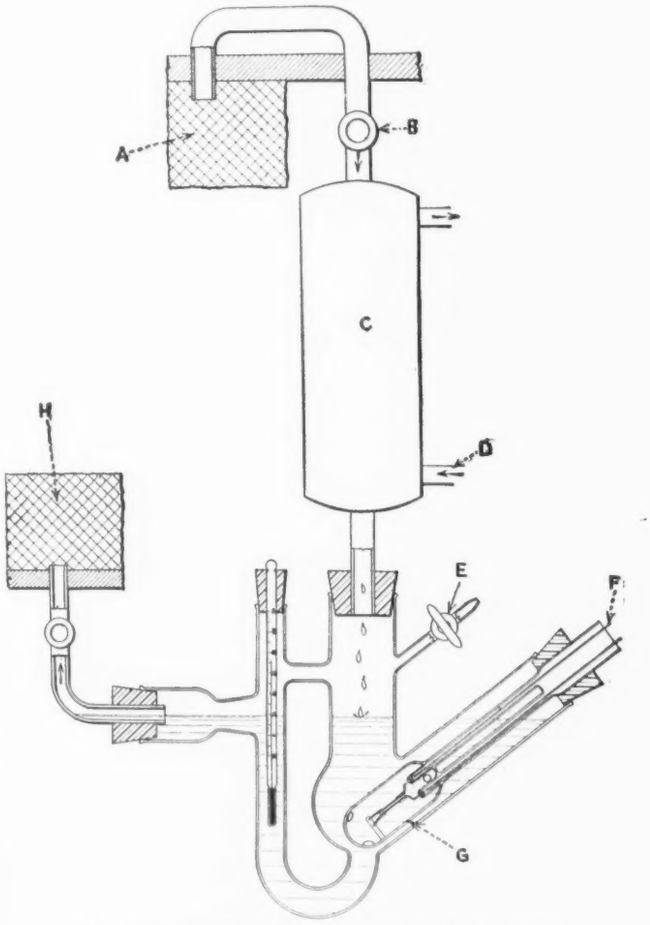


Fig. 2—Condensed steam sampling apparatus

its construction without danger of contaminating the condensed steam.

It was found from operating experience that it was necessary to have the condensed steam flowing through the cell for nearly half an hour before the cell was washed free from contamination. It was also found that the flow of water through the cooling coil could be adjusted so that the temperature of the condensed steam would closely coincide with that of the condensate. This reduces the magnitude of the temperature correction which it is necessary to apply in the calculations for leakage.

In the subsequent calculations it will be assumed that all the measured values have been reduced to the same temperature. It is not necessary, but it is convenient, in comparing the results from day to day, to have all values reduced to one standard temperature.

In reducing a measured conductance, L_m, at a temperature, t_m deg. (expressed in degrees F.) to a standard temperature, t_s, it is only necessary to multiply by a ratio which is found by adding 5 deg. to the standard tempera-

ture and dividing by the measured temperature plus 5 deg. The conductance at standard temperature, L_s, is then: (Reference 4.)

$$L_s = \frac{L_m(t_s^\circ + 5)}{(t_m^\circ + 5)} \qquad (1)$$

For small temperature differences it may be easier to assume a linear coefficient of 1.2 per cent per degree F.

The Condensate Cell

In measuring condenser leakage it is also necessary to determine the conductance of the condensate. At the right side of Fig. 4 is shown the cell developed for this measurement. The sample may be drawn from the pressure side of the hotwell pump. On account of having an ample supply of condensate for thoroughly washing out the cell, it is relatively easy to avoid contamination of this sample. Reproducible results are readily obtained. The same pair of electrodes can be used as are shown in the steam cell, but when a series of measurements are taken, it is more satisfactory to use another pair, in order to avoid interference with the readings of the steam cell.

When two pairs of electrodes are used in the leakage measurements (one for measuring the condensed steam and the other for measuring the cooling water and condensate), it is necessary to determine the ratio of the constants of the two cells. This is easily done, and but a single determination is necessary, since the ratio should remain fixed and independent of the temperature, unless the electrodes are platinized or accidentally displaced. It is only necessary to determine the resistance or conductance of any given solution (preferably having a resistance

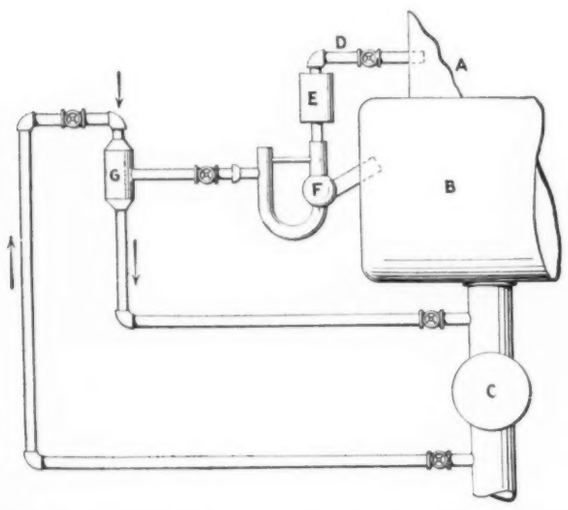


Fig. 3—Optional Method of Collecting Steam Sample

of a few hundred ohms), with the two pairs of electrodes. The ratio r used in the subsequent calculations is the measured resistance of the steam cell electrodes R_s divided by the measured resistance of the condensate cell electrodes R_c. Then

$$r = \frac{R_s}{R_c} \qquad (2)$$

In reading the conductance it was found advisable to move the electrodes slowly through the sample while readings were being made. This removes any danger from local heating or contamination of the solution in the neighborhood of the electrodes.

It is perhaps not surprising that the Kohlrausch method of using alternating current with telephone receivers has never been widely applied in industry to eliminate the error from polarization, due to the obvious difficulties of using an acoustic method. However, after the development of the alternating-current galvanom-

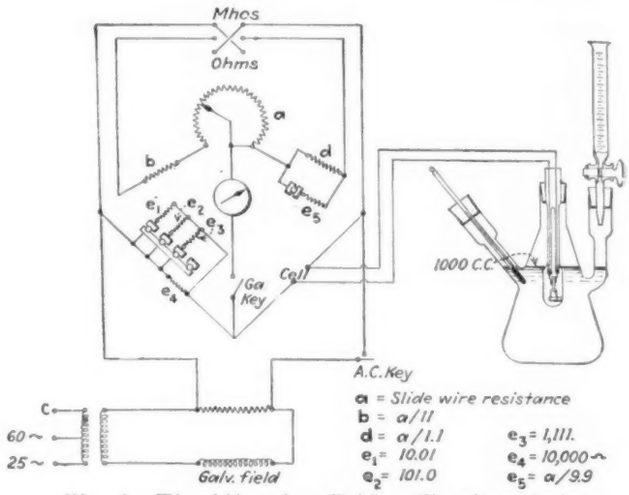


Fig. 4—The Mho-ohm Bridge Circuit and the Condensate Dilution Cell

eter, which gives a visual method, equal in all respects to that obtained with direct current, it seems strange that the direct-current instruments have not been entirely superseded.[7] The reason for this is probably explained by the fact that there have been no alternating-current bridges available with a scale reading in conductance units. This deficiency has now been satisfied by the development of the Mho-ohm bridge shown in Fig. 5.

The Mho-ohm bridge is a portable instrument of convenient size, reading from 1 to 12,000 ohms or from 1×10^{-5} to 0.1 mhos (reciprocal ohms) to an accuracy of 1 per cent. The scale of the instrument is uniform in either mhos or ohms. Current is supplied from a lighting circuit of 25 or 60 cycles. The readings in mhos give relative conductance values. For absolute values these readings are multiplied by the constant of the cell, but this calibration is not required in making leakage measurements. The diagram of conections used in the instrument is shown at the left in Fig. 4.

In Fig. 6 are shown two curves which were obtained by adding various concentrations (expressed in per-

[7]Digby's apparatus was obviously designed for only rough measurements, since the use of a direct current had long since been shown to be subject to considerable errors. Digby apparently recognized this when he states: "On the electrochemical side the effect of polarization has to be eliminated." Although he recommended circulating the liquid to reduce this effect, no provision for doing so was included in his apparatus. In recent modifications it has been variously claimed that polarization is reduced by increasing the distance between the electrodes or is eliminated by an "allowance" in the scale of the instrument. The first point has never been proved, and it is also obvious that any "allowance" in the scale must be only approximate, since polarization varies with the concentration, voltage and even with the composition of the solution. Upon increasing the distance between the electrodes the voltage must be raised to obtain the required sensitivity for the instrument, but this increase in voltage increases the polarization once more. This fact makes it doubtful whether any considerable advantage is gained in this manner.

centage of cooling water to a liter sample of condensate contained in the condensate cell, Fig. 4. The conductance values on these plots and in the remaining portion of the article are multiplied by 10^5, for the convenience of dealing with whole numbers.) In making these measurements the cooling water was introduced from the burette, which is calibrated directly in Percentage Leakage. The solution was stirred, and the temperature was read at the same time that the conductance was determined in order to correct the readings to the standard temperature.

Some important conclusions may be drawn from these curves. It will be noted that, in the one case, the conductance of the river water, L_{rw}, was over twice what it was in the second case. However, the ratio of these conductances to the slope S of the corresponding lines is nearly constant (changing only 0.7 per cent). This shows that the slope is nearly directly proportional to the conductance of the river water. It is evident, therefore, that *the slope of these curves may be determined by measuring the conductance of the river water at the standard temperature and by dividing this value by an average factor.* This conclusion has been confirmed by the authors in measurements taken upon several other river waters. In fact, it has been found that an average value for this factor of 91.5 may be used, without appreciable error, for calculating the value of S for any inland river water that they have examined. The maximum deviation found from the value 91.5 has been 3 per cent, which would cause a negligible error in the calculated leakage. Thus, if the true factor were 89 and if the true leakage were 1.0 per cent, the calculated leakage (using the factor 91.5) would have been 1.03 per cent, which is within the experimental error.

It was also found in these measurements that the slope

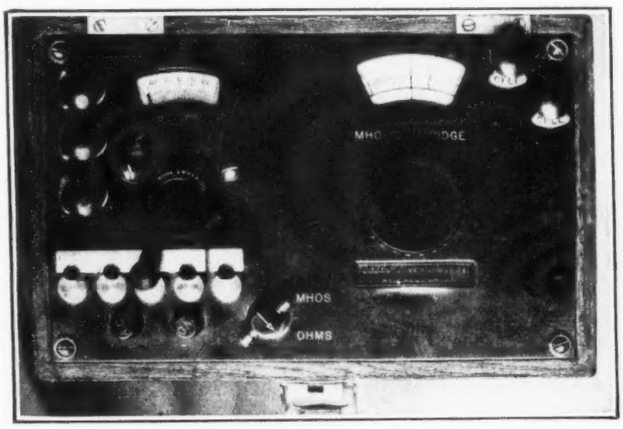


Fig. 5—The Mho-ohm Bridge

of these curves may be determined by making the foregoing measurements in laboratory distilled water as well as in condensate or condensed steam. The same sample of river water, tested in these three different types of distilled water, gave values for S of 2.83, 2.82 and 2.85 respectively.

The value of S may be considered as being the corrected conductance of a 1 per cent solution of the cooling water. (The "correction" is made by subtracting the residual conductance of the water from that of the mixture.) Its value may most easily be determined by measuring the conductance of the river water and dividing by 91.5 or by a factor which is more suitable to the particular river water and which has been determined by dividing the conductance of the river water by the slope of the Percentage Leakage curve (Fig. 6). The slope of this curve may be found satisfactorily by subtracting the conductances of a 0.5 per cent and a 1.5 per cent solution. If a third concentration of 2.5 per cent is measured, a check upon this value is obtained by subtracting

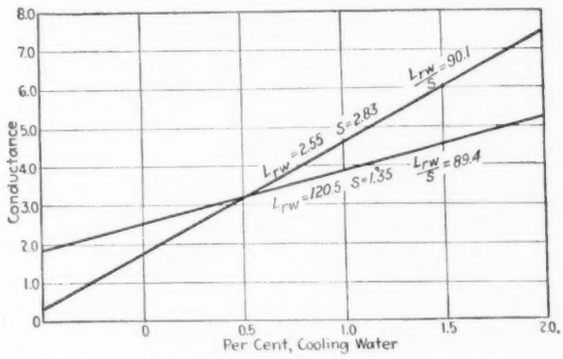


Fig. 6—Conductance of Cooling Water Solutions in Condensed Steam

the conductance of the 1.5 per cent solution from the latter.

In making use of the quantity S for calculating condenser leakage, it is necessary to reduce its value to the standard temperature. This is accomplished by the use of Equation (1), or by applying a linear coefficient of 1.2 per cent per degree F.

If the corrected conductance of a 1 per cent solution of the circulating water (that is, if the value of S) is known, it is evident, from the fact that the curves in Fig. 6 are straight lines, that the percentage of any concentration of any solution may be determined by dividing its corrected conductance by the conductance of the 1 per cent solution. In measuring condenser leakage the conductance of the condensate is "corrected" by subtracting the conductance of the condensed steam sample. This corrected conductance divided by S will give the Percentage Leakage of the condenser. Provided the same electrodes are used throughout, we then have

$$Percentage\ Leakage = \frac{L_c - L_s}{S} \qquad (3)$$

If a separate pair of electrodes are used in the steam cell and if the cell constant ratio is r, Equation (2), we have

$$Percentage\ leakage = \frac{L_c - L_s \cdot r}{S} \qquad (4)$$

If the value of S is expressed in terms of the conductance of the river water, L_{rw}, the above equation becomes

$$Percentage\ leakage = \frac{91.5\ (L_c - L_s \cdot r)}{L_{rw}} \qquad (5)$$

The general method for the determination of the percentage leakage, therefore, consists in the measurement of three quantities: First, the conductance of the condensate, L_c; second, the conductance of the condensed steam, L_s; and third, the conductance of a 1 per cent solution of circulating water, S, or alternatively, the

conductance of the circulating water, L_{rw}. These quantities are either measured at or reduced to the same temperature by Equation (2), and are then substituted in Equations (3), (4) or (5).

The percentage leakage varies with the load. Thus, if the number of pounds of water per hour leaking into the condenser remains constant, it is evident that the percentage leakage varies inversely with the load. If the latter is doubled, the leakage is halved. To convert the readings into pounds of water per hour leaking into the condenser, the Percentage Leakage is multiplied by the

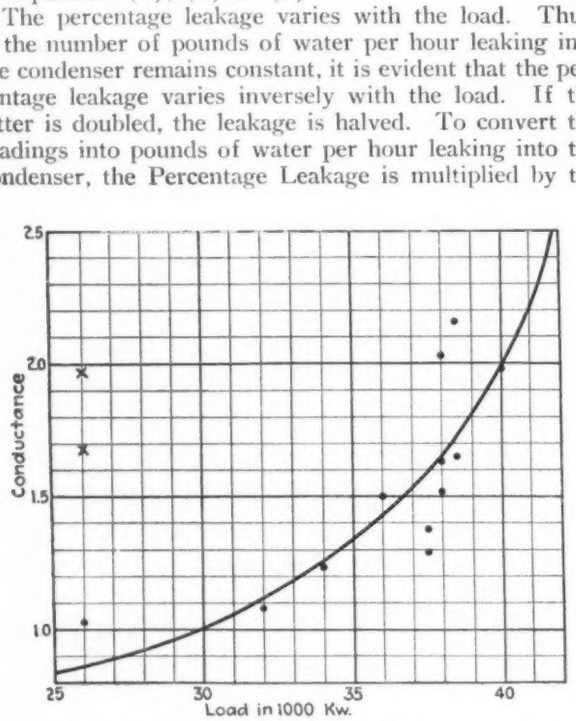


Fig. 7—Conductance Values of Condensed Steam at Different Loads

load expressed in hundreds of pounds per hour. The leakage expressed in this manner should remain substantially constant, and this fact provides one of the best tests of the accuracy of the leakage measurements.

Operating Data

In the table are presented the data which were obtained at the West Penn Power Company during a short series of leakage measurements. The relative conductance values contained in this table are based on the constant (0.119) of the condensate cell, and when multiplied by this factor, the results will be expressed in specific conductance. In the table are given, beginning with the second column, the conductance of the river water, the calculated value of S, the measured value of S, the relative conductance of the condensed steam (based on a cell constant of 0.0509), this conductance reduced to a cell constant of 0.119, the conductance of the condensate, the load, the calculated Percentage Leakage and the calculated pounds of water leaking in per hour.

In Fig. 7 are shown plotted the results obtained when measuring the condensed steam at a series of different loads. When these measurements were made, the new steam cell was not available. The condensed steam was collected in a flask and consequently the measurements contain a large experimental error which is plainly indicated by the plot. However, from measurements carried out at the Philadelphia Electric Co., the shape of the curve was known within a fair degree of accuracy, and hence it is believed that the curve shown in Fig. 7 represents typical conditions. The two points indicated by crosses were made just after the load had been suddenly reduced, and it is believed that this accounts for the discrepant values. During the measurements, which were taken with the steam cell, the load on the turbine could not be reduced without interfering with the plant operation and hence it was impossible to obtain more satisfactory data from which to draw this curve.

Steam Quality

Several interesting points were found in the measurements taken at the West Penn Power Co. In the first series of measurements (July, 1925) the condenser leakage was apparently very low (this could not be actually determined, since the new steam cell had not been installed), and remarkably low values for the conductance of the condensate were obtained. The lowest value of the specific conductance was 1.32×10^{-6} at 85 deg. F. This is considerably better condensate than has ever before been reported. (Digby's best value was 3.3×10^{-6}.) The best value obtained for the condensed steam was 1.22×10^{-6} at 85 deg. F. With a cell free from all contamination this would have been reduced still further.

In the second series of measurements (April, 1926) the best condensate obtained was 2.9×10^{-6}, but with the new steam cell a minimum value, for the condensed steam of 1.07×10^{-6} was found at a load of 39,000 kw. Judging from the curve shown in Fig. 7, it is indicated that this value would be reduced to about 0.6×10^{-6} at a load of 25,000 kw. These values represent water that is as pure as can be obtained by double distillation in the research laboratory, without special precautions against contamination from the air.

At the West Penn Power Co., sodium phosphate is used in the boiler treatment, and from the foregoing data it is evident that this substance (as would be expected) is extremely non-volatile. If soda ash were used in treating the water, the quality of the steam would undoubtedly be greatly reduced.

CONDENSER LEAKAGE MEASUREMENTS

Steam Cell Constant = 0.0509. Condensate Cell Constant = 0.119.
r = 0.427, 1 Kw. = 8.83 lb. Steam.

Date	L_{rw} (85° F.) $\times 10^6$	S, from $L_{rw}/91.5$	S, from Dilution	L_s (85° F.) $\times 10^6$	L_{sr} (85° F.) $\times 10^6$	L_c (85° F.)	Load in 1,000 Kw	Percentage Leakage $\frac{L_c - L_s}{S} \times R$	Pounds Leakage per Hour $= \frac{\text{Load}}{\text{Leakage}} \times 8.83 \times \%/100$
April 21 —1:00 p.m.	120.5	1.32	1.35	2.23	0.95	2.52	37.5	1.22	4,040
April 22 —1:00 p.m.	137.5	1.50	....	3.56	1.52	3.51	32.5	1.33	3,820
April 22 —2:30 p.m.	137.5	1.50	....	2.88	1.23	2.81	39.0	1.052	3,630
April 22 —4:30 p.m.	137.5	1.50	....	2.18	0.93	2.50	39.0	1.046	3,600

Minimum value of specific conductance of condensed steam = 1.07×10^{-6}
Minimum value of specific conductance of condensate = 1.32×10^{-6}

Tests of the Reliability of Leakage Measurements

The data in the table show that the same quantity of water per hour was leaking into the condensers during the time required for the measurements. The same value (within the experimental error, or within actual variations in the leakage) was obtained, even though the load was varied. This is generally the best method available for testing the reliability of the leakage measurements.

In measurements at other stations it has been found

that, except for minor fluctuations of the order of 5 to 10 per cent, the quantity of water per hour leaking into a condenser normally shows a slow decrease with the time. (A considerable increase in leakage is shown immediately after cleaning the tubes.) The data given in Table I show a trend in the proper direction, and this would tend to establish their accuracy.

Another test of reliability would be a comparison of the results with those obtained by a direct weight method. It is somewhat doubtful, however, whether the quantity of leakage per hour would be the same after the turbine was shut down, since the vibration of the turbine would influence the results to some extent.

Measurements with Salt Cooling Water

When salt water is used for cooling, the measurements are simplified and their accuracy increased. This is due to the great change in conductance which is caused by a small leakage. The conductance of the condensed steam can, in general, be entirely neglected and Equation (3) would then become

$$Percentage\ leakage = \frac{L_c}{S}$$

The factor corresponding to 91.5 for river water will be *lowered* and will be found to approximate the value 63.0. In this case, if L_{sw} is the conductance of the sea water.

$$Percentage\ leakage = 63 \times \frac{L_c}{L_{sw}}$$

For these measurements comparatively crude instruments may be used.

Recording Percentage Leakage

In the measurements taken at the Philadelphia Electric Co., extending for over a year, it was indicated that a curve similar to that shown in Fig. 7 would hold with fair approximation for the conductance of the condensed steam. It is also true that the conductance of the average river water changes rather slowly unless rains have occurred. Hence, if a curve similar to Fig. 7 has been determined, and if the conductance of the circulating water has been measured recently, the condenser leakage can be estimated by a single measurement of the conductance of the condensate. This is therefore the most important of the various quantities to measure, and it has been found advisable in a large number of power plants to make a continuous record of this value. A removable conductivity cell which requires very little attention is installed directly in the condensate line. This cell does not even require platinizing, since a new treatment of the electrode surface is used which eliminates polarization. The cell is made with a special bakelite insulation which makes a water-tight joint without the use of cements or packing joints. When the recorder is equipped with a bell alarm or signal lights a warning may be quickly given in the case of a split condenser tube, for instance.

It is also possible, with a new recorder which has been developed, to record the actual percentage leakage. To explain the principle of this recorder it may be noted from Fig. 6 that the conductance of the condensed steam itself may be represented as a certain percentage leakage, provided the zero of the latter scale were moved over to the point where these lines cross the axis of zero conductance. The recorder scale may be calibrated in terms of the new units which may then be called *apparent* percentage leakage. It is evident that, if a two-point recorder were used with a scale calibrated in apparent percentage leakage and if the two points were atached to the steam cell and condensate cell, respectively, the difference in the two readings would be the true Percentage Leakage.

What Do You Know

The answers are on page 490

ALL plants have some kind of pump, but so reliable is this kind of apparatus that we take a lot for granted about the how and why a pump works. Here are ten questions covering things all ought to know about direct-acting pumps. Can you answer them?

Ques. 1—Suppose one of the piston rods of a 6x4x6 duplex boiler feed pump had to be renewed and that the new one, when received, did not have the location of the valve rocker spool marked. How would you know where to set the spool on the rod?

Ques. 2—Why is a submerged-type pump, that is, one in which both the suction and discharge valves are placed above the water cylinder, not suitable for large capacities?

Ques. 3—What is meant by the term "outside center-packed"?

Ques. 4—Why is the pot-valve pump design used for high pressures?

Ques. 5—In a compound duplex direct-acting steam pump without flywheels, does the steam act expansively in the high-pressure cylinder?

Ques. 6—Suppose you needed a duplex pump with which to handle ammonia liquid. Of what material should the pump end be?

Ques. 7—Suppose a duplex pump short-stroked. How would you correct this?

Ques. 8—Can you lift water higher operating a pump slow or fast?

Ques. 9—What is a water-works condenser as used with pumping engines?

Ques. 10—Is it possible to have a pump with the steam cylinders exhausting into the suction of the water end?

Some Notes on Steam Turbine Development

V. Designs of Bearings and Bearing Housings

By W. J. A. London

ALTHOUGH the casing itself is the stationary element of major importance, experience has taught several lessons regarding the proper design of such parts as the bearings, the bearing housings, etc.

In studying this matter from the viewpoint of the engineer or draftsman, accustomed to the design of reciprocating engines and the like, it is but reasonable to expect that he would take into account only such items as the light weight of the rotating elements and the absence of any necessity for providing against shock, and proportion his scantlings accordingly.

Vibrations of a very minute order, emanating from the rotor or from external sources, either direct or through synchronism, may produce unpleasant vibrations in the valve gear and in the whole machine itself, the source of these vibrations often being hard to determine. Again, a machine may appear to be running perfectly as far as balance is concerned, yet set up a very marked and objectionable trembling in the engine room quite a distance away.

EXPERIENCE and changing conditions have been responsible for much of the progress in turbine design. Mr. London, in his fifth article, traces the path to modern practice in the design of turbine bearings, blade clearances and turbine disks.

It has therefore become established practice in more recent years to put more *beef* into such parts as the bearings and their housings, the governor gear, etc.; in other words, to design these parts much more sturdily than would appear on the surface to be necessary, bearing in mind only the mechanical duty the respective parts have to perform.

Progress in Bearing Design

In Fig. 1 are shown two interesting designs illustrating what was at one time considered conservative practice in bearing design as compared with more recent practice. In this connection the difference in bearing proportions—that is, the ratio of the length to diameter of the bearings themselves—should be noted. For many years it was established practice to make the bearing length three or four times the diameter, but in recent practice this ratio is reduced to 1:1 or 1:2 at the outside. We are considering only large machines where forced lubrication is used, because in small turbines where ring oiling is sufficient larger ratios must be resorted to in order to keep the peripheral speed within the limits of the ring speed.

In long bearings (in proportion to the diameter) it is obviously difficult to obtain a uniform bearing pressure throughout, especially if the bearing is of light construction, whereas in a properly designed bearing, having sufficient rigidity so that it will not deflect perceptibly under load, a much higher *apparent* pressure per square inch may be employed, whereas in reality the unit pressure may be no greater than in a long slender bearing.

In any case, as the result of research work, with regard to both material and design, much higher specific loads and rubbing speeds are now used than were considered safe ten years ago.

Apart from the bearing shell itself it is highly important that the housing be designed to give adequate support to the bearing. An example of bearing support of inadequate strength, used in some of the earlier large turbines, is shown in Fig. 2. In this case, when the rotor was dropped into position the deformation was sufficient to close in the sides of the bearing shells, necessitating considerable scraping before the bearings could operate satisfactorily.

Considering again the long bearings, mounted in spherical seats, it is often assumed (erroneously, of course) that, because of this method of mounting, the bearing shell will at all times adjust itself into true alignment with the shaft, and thereby equalize the unit pressure. The spherical seat does not "work" or rather, cannot do so in operation, as this shell is clamped tight in the housing. This form of seat is provided for initial alignment only.

Cooling of Turbine Bearings

With regard to the cooling of the bearing or the oil in the bearing, various systems have been tried and adopted to do this locally—that is, in the bearing itself—either by casting the shells hollow and circulating the cooling water through these cored jackets or by casting cooling coils in the babbitt. All such methods are inefficient and complicated and have the added danger of possible leaks from the water chamber into the oil. The almost universal practice now, therefore, is to cool all the oil in a well designed and efficient cooler.

In the smaller turbines, where forced lubrication is not used, some form of local cooling is necessary with high operating temperatures—not so much to carry away

the heat caused by friction in the bearings as to reduce as far as possible conduction from the casing to the bearing. This is generally accomplished by casting a cooling chamber in the housing or inserting coils in the oil well.

Design of Rotating Parts

The general design of the rotating parts of steam turbines is of such vast proportions that it can be touched upon only briefly in this article, and then only with reference to some of the peculiar phenomena that have been discovered in recent years and that are foreign to the general calculations pertaining to centrifugal stresses, critical speeds, etc.

Blade Stripping and Clearances

Reference has previously been made to blade stripping, a trouble so prevalent in the early reaction machines and causing much worry on the part of the builder and apprehension on the part of the purchaser. Furthermore, it was pointed out that this trouble often occurred without any apparent reason; the clearances were ample and the blades did not give out at the roots. The phenomenon of blade vibrations had not been investigated. The earliest experience of the positive presence of this phenomenon was on a test of an early 3,000-kw. machine built by one of Parsons' licensees. The low-pressure blades were 9 in. long and were laced at the outer end only, this being the standard Parsons practice at that time. This lacing was primarily for stiffening the blades for machining. What was considered to be ample radial clearance was allowed. These blades stripped on the first test. The machine was rebladed with more clearance. The same thing happened on the next test; then, after again reblading, an abnormal leeway was given so that, when compared with the adjacent stage, there could be no possibility of fouling, but the blades still stripped. The company was naturally in a quandary, and Professor Stoney (then chief of the Parsons company) was called in for consultation, and he should be given credit for diagnosing the trouble as that due to blade vibration. The blades were replaced, allowing the initial clearance, but the blades themselves were laced in the center as well as the ends, and no more trouble was experienced. This was the origin of the present practice of multiple lacing.

After exhaustive research along these lines the period of vibration in turbine blading can now be calculated with surprising accuracy.

Breaking of Turbine Disks

The breaking of several high-speed disks, where the characteristics of the material were known, and the factor of safety, based on all known methods of calculation, ample, introduced another phenomenon of intense interest.

The seriousness of the accidents referred to demanded drastic action, and the General Electric Co. is to be congratulated on the thorough manner with which it attacked and solved this problem and the ingenious methods employed to fathom and analyze the phenomenon now so well known as the *lateral vibration of disks.* Through the generosity of the above-mentioned company, the results of the experiments to date have been so freely published, in the recent technical press, that nothing of value could be added here.

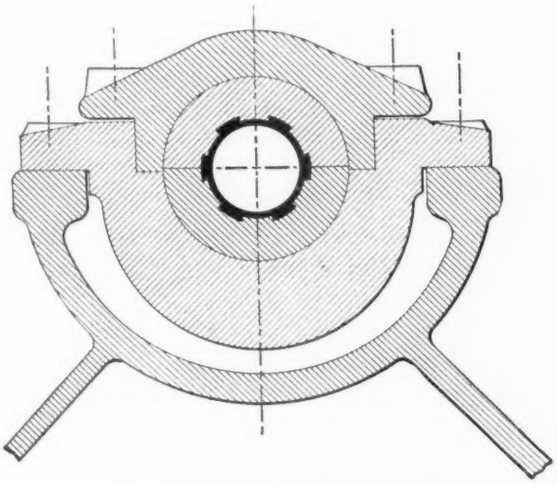


Fig. 2—Example of bearing support of inadequate strength

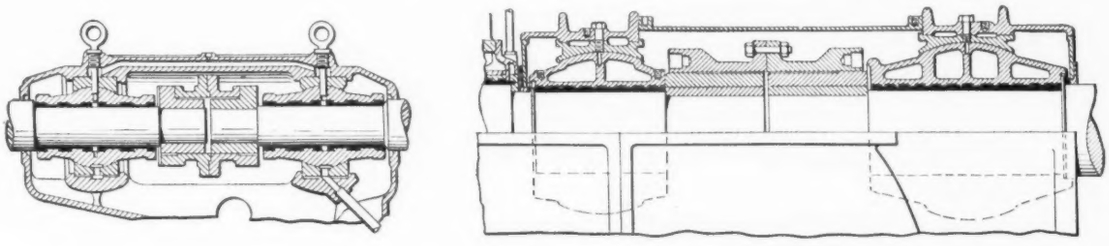


Fig. 1—Two designs of turbine bearings

Left view—Conservative design used in past. Right view—Modern practice in bearing design.

WATCH *for the*
ANNOUNCEMENT
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Early in October
First Prize $500
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EDITORIALS

F. R. LOW, *Editor*

An Excellent Report

MANY excellent reports have been issued from time to time by the Prime Movers Committee of the N.E.L.A., but few have surpassed, in wealth of useful information, that just put out by the Subcommittee on Pulverized Coal. Credit is due not only to Chairman Thompson and his associates on the Committee, but also to the member companies and industrial plants for their co-operation in supplying data and frankly discussing operating difficulties.

An abstract of the report appears elsewhere in this issue. One is impressed by the number of installations, especially in industrial plants, also by the extensive use of the unit system, which now outnumbers the centralized system three to one.

Total preparation costs per ton of coal fall within a close range, although the component items of energy, maintenance and labor vary considerably in different plants. On the other hand, there appears to be no general agreement as to the moisture content above which trouble will be encountered, notwithstanding the well-understood difference between surface and inherent moisture. Obviously, the type of equipment and character of the coal are factors to be considered with the moisture content.

Differences of opinion are evident as to methods of sampling, and this might well bear careful study.

The fine ash is still giving concern in some quarters, but the matter of furnace walls now appears to be fairly well in hand. One by one the perplexing major problems are being "licked," leaving such secondary ones as are peculiar to development in apparatus and to local conditions.

Theory and Practice

THEORETICALLY, certain things should happen, but practically, the results are otherwise. How often one hears the statement! Too commonly, in the face of a report of observed occurrences, somebody announces sagely that such a thing is theoretically impossible. All of this is an outgrowth of a gross misconception of the place of theory and experience in scientific and engineering fields.

Mankind has built up a body of recorded experience on diverse subjects that is so vast in its range and so complex in its relationships that without some effective condensation and correlation it would be utterly useless because it would be impossible to transmit it from man to man within a single lifetime, if for no other reason.

Theory is simply a systematic statement of this accumulated experience—or experiment, if one prefers the word—classified and codified and formulated to promote convenience in its application.

Theory is not something above experience, sitting as judge over our observations with a sort of veto power. It is rather a careful record of what has gone before.

Naturally, if an observer reports seeing a blue horse or an eight-legged dog, his hearers tend to question the accuracy of his observation, although theory is not wholly wanting to explain the origin of reports of that nature.

But when fully substantiated observations disagree with theory, what is to be done? The observations are fully substantiated; they cannot be set aside. Shall theory be discarded altogether? By no means. The only adequate remedy is more theory, better theory, with some of the old restrictions removed. It will probably be a more complicated theory, but that can hardly be avoided, since the very occasion for its development is usually an excursion into new and untried fields among conditions hitherto unknown.

There has long been a well-developed theory, based on careful observations by many good men, by which it is possible to calculate the rate at which steam will flow through a nozzle. A few years ago, with higher steam pressures and temperatures, better nozzles and more refined methods of testing, results were obtained indicating that more steam actually flows than this theory accounts for. Checking and rechecking confirmed the observations. It became evident that the old theory had failed to include all the facts.

Supersaturation is the fact that was formerly unsuspected. On another page of this issue *Power* is glad to present to its readers the first of two articles explaining the significance and bearing of this feature in the rapid expansion of steam. While this discussion may not affect the operating engineer as does scale in his boiler tubes, it is nevertheless a matter of importance to every user of a steam turbine. The designer must take it into account in building a turbine to make the most efficient use of steam, and the operator can at least derive some intellectual satisfaction from acquaintance with the subject. Every man in the steam field should know something about it. Professor Goodenough's articles will help.

Efficient Loading of Power Generating Units

A REDUCTION of one per cent in the water rate of a steam plant would be considered by designing engineers a real accomplishment. A great deal of time and study would be given to making such a gain in efficiency possible and to justify it economically. Notwithstanding this, plants are in operation in which little or no attention is given to the loading of the machine. This one factor alone may materially affect the water rate of the station, particularly where the machines are of different types and sizes.

In a number of the larger plants and systems load schedules are used to good advantage. Operating engineers in medium- and small-sized plants have not been inclined to give the attention to this feature of operation that its importance merits. When the units in these plants are kept fairly well loaded, it is generally considered that this is about all that is required so far as efficient loading is concerned.

As shown in the leading article in this issue, the division of load among the units has a marked effect on the station water rate, even in the small plant. With the station on which the discussion is based having a rating of seven thousand kilowatts and carrying a load of forty-five hundred kilowatts, there is a difference of over four thousand pounds in the steam consumption between the least and most efficient loading of machines. Taking a steam cost of fifty cents per thousand pounds, this difference is over two dollars per hour. From this it is evident that the operator can easily save his salary even in a small plant, by giving attention to the proper loading of the machines.

As shown in the article referred to, a loading schedule may be worked out by simple arithmetic. Therefore, even in the small plants there is no reason for the lack of a better understanding of the loading of the machines, even if a technically trained engineer is not available to make such a study. The operating engineer can work out such a schedule for himself, and probably by the time he has completed the study, he will find an entirely new interest in the plant's operation.

This study should not only cover the best combinations of machines to carry a given load, but also include careful observation of the average load conditions. It is of equal advantage to guard against keeping units in service that are not needed to carry the load safely and insure continuity of service and to divide the load properly between the units in operation. This is one way to improve the operating efficiency of a plant that does not require the management's approval of an appropriation. It may also be the means of obtaining approval for needed appropriations, which, as most engineers know, is not always an easy matter to persuade the management to give.

What About Depreciation of Machinery?

MUCH confusion exists among engineers and managers as to the proper overhead charges to be assumed when considering the installation of new machinery.

In a strictly engineering sense depreciation charges should be such that this sinking fund will cover the cost of the machine when it wears out. This is the proper charge to make when calculating the actual cost of operation when the machine is already in existence. With the operating costs so calculated, any savings over operation by another machine is profit.

Applying this to an examination of the comparative advantages of continuing the use of an old power plant and of building a new one, the new plant must show sufficient savings over the old one to justify its installation. A difficulty arises when deciding upon the proper depreciation to assess against the contemplated plant. In an engineering sense there will be depreciation if the plant is actually installed. But it is questionable if such a charge should be placed when examining the advantages of installing the new machinery, although this statement may seem illogical.

Business in general insists that new equipment must show a gross profit of about twenty per cent to be attractive. This means that the machine must pay for itself within five years. Depreciation and interest are included in this gross profit; otherwise the desired gross profit plus overhead would cause the machine to pay for itself within less than three years. As long as business insists on being shown a gross profit by a new installation, no fixed charges on the new equipment should justifiably be made. On the other hand, to the new equipment price must be added the present worth of the machinery to be discarded less the junk value.

When a contrary course is pursued, for example, when comparing the cost of purchased energy and that of power generated in a new plant, the setting up of fixed charges may cause the plant to need ten years to pay for itself, when in fact it will be paid for in five years, and after that time no fixed charges should exist because the capital investment has been returned.

WHERE FUEL IS EXTREMELY CHEAP, refinements in equipment, calculated to recover stray heat units, are generally considered unjustified. The acid test is that the savings must more than offset fixed charges and maintenance upon such equipment. Lack of such refinements, however, does not always preclude an opportunity to effect substantial economies through careful study of possible wastes, rearrangement of service lines and close attention to operating procedure. Those responsible for plants operating with cheap fuel would do well to read what Mr. Nevius has to say of the Commercial Solvents plant at Peoria, in last week's issue.

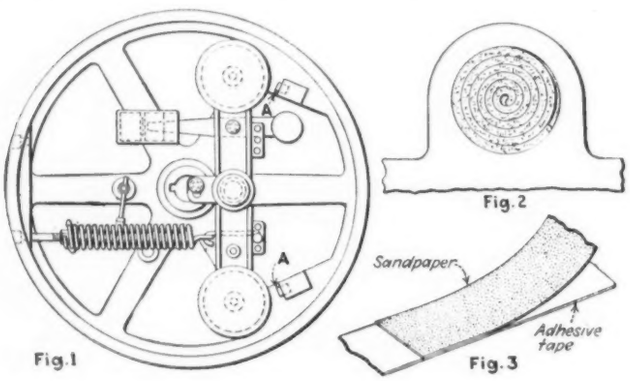
IDEAS *from* PRACTICAL MEN

Readers are urged to use this department for the exchange of practical operating information. A minimum of five dollars will be paid for contributions accepted

Meeting Emergencies in the Power Plant

SOME time ago I was badly in need of a rubber governor-arm stop in the form of a plug 1½ in. in diameter by 2½ in. long to fit in a recess in the flywheel rim as at *A*. As there was no chance of getting one for several days, I cut a strip of sheet-rubber packing 2½ in. wide and long enough to roll tight into the required diameter and forced it into the recess, as shown in Fig. 2, and it worked satisfactorily. In fact, I am of the opinion that it will give longer service than the solid rubber owing to the fact that its spiral laminations tend to prevent cracking under the heavy blows from the governor arm.

On another occasion I was working at midnight putting a new bearing sleeve in a motor and needed a strip of emery cloth to clean the shaft. There happened to be none on hand, so I was obliged to use sandpaper. The paper was first cut into strips two inches wide, then



Figs. 1 and 2—Governor-arm stop made from sheet-rubber packing. Fig. 3—Strip of sandpaper reinforced

reinforced by sticking on its back strips of adhesive bandage off a 2-in. roll from our first-aid kit. This made a cleaning strip even stronger than emery cloth and the paper showed no tendency to peel off.

Vancouver, B. C. R. MANLEY ORR.

Keeping a Pump Primed Without a Foot Valve

ON ONE occasion a large steam pump refused to take water when it was wanted in an emergency. An examination of the foot valve showed that it had become clogged with leaves in such a way that the clapper was held off its seat. This had permitted the pump to drain out, and the valves had got dry from standing without water in the valve chamber.

This experience led to the arrangement of piping that would prevent the pump from losing its water and at the same time do away with the foot valve. The end of the suction pipe was protected against the entering of large pieces of foreign matter and fish by attaching a

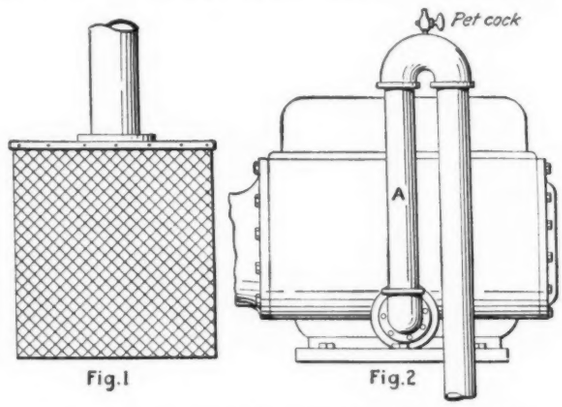


Fig. 1—Large-mesh screen for suction pipe
Fig. 2—Arrangement of suction pipe to keep pump flooded

large basket-shaped, large-mesh screen to the end. This is shown by Fig. 1.

Fig. 2 shows the arrangement of the suction pipe. This was run up a little higher than the valve chamber of the pump, using a return elbow at the top. In this return bend an air cock was fitted, as shown. After the pump was used, which was intermittently, the air cock was opened, thus separating the column of water in the two vertical pipes. Thus, the drop pipe *A* remained full of water and the pump was kept primed.

Columbus, Ga. D. W. CLARK

Safety First When Working on Potential Transformers

AN ELABORATE clearing operation is carried out in an up-to-date power house when any electrical equipment is to be worked on—especially circuits of 2,300 volts and over. Many systems for the protection of workmen against injury caused by the accidental or careless closing of circuit breakers require those concerned to follow a definitely specified procedure, and the switchboard operator places a "clearance card" on all switches controlling the circuits cleared. Such cards are not to be removed until the man in charge of the work

reports in person that everything is in order and all workmen clear. Precautions such as these are necessary to insure against mistakes which might result in fatal injuries. No other measures are taken in many cases, and it is the privilege of those concerned to use ground chains or not as they desire.

Cases have come to my attention, however, in which a person begins work on the primary of a potential transformer with only the high-voltage side properly cleared, no attention being paid to the instrument side, as the

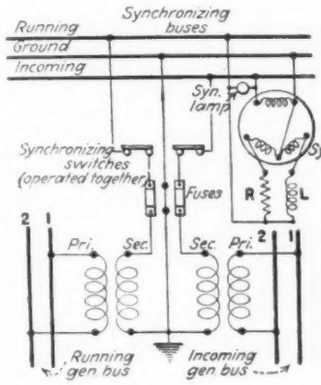


Fig. 1 — Closing synchronizing switches caused shock on primary of dead transformer

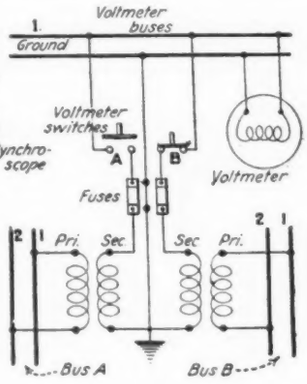


Fig. 2—Transformer energized from another line through voltmeter bus

potential on that side is not normally dangerous if it should be touched. Often a workman does not realize the effect on the primary side of a small current in the secondary as a result of the step-up ratio from secondary to primary.

I have seen a severe shock received from the primary of a potential transformer when the high-tension switches were visibly open in a case such as that shown in Fig. 1. A synchronizing plug was in on the switchboard, and the secondary of a potential transformer was being energized through the synchronizing lamps in parallel with the windings of the synchroscope. As the lamps glowed only faintly and the synchroscope pointer was stationary, it was not noticed that the transformer secondaries were energized. Such a shock will usually not cause any serious injury as far as electrical effects are concerned, but minor shocks occurring unexpectedly may result in dangerous falls when the man is working off the ground. Linemen are especially familiar with this because of the effects of "static" induced on a dead line by a neighboring energized high-tension line.

A man went to the hospital in one instance as the result of an accident while he was standing on the floor working on a small potential transformer which operated a voltmeter, as shown in Fig. 2. The voltmeters were of the old style and did not have a common key or plug. A meter could be turned on at any time, the operator's discretion being relied upon to prevent two switches being on at once. But in this case the dead switch *A* was turned on while the voltmeter bus was energized. The secondary fuses were blown, but not until a bad shock was received from the primary of the transformer. Accidents of this nature may be avoided by removing the secondary fuses of the de-energized potential transformers.

E. H. STIVENDER.

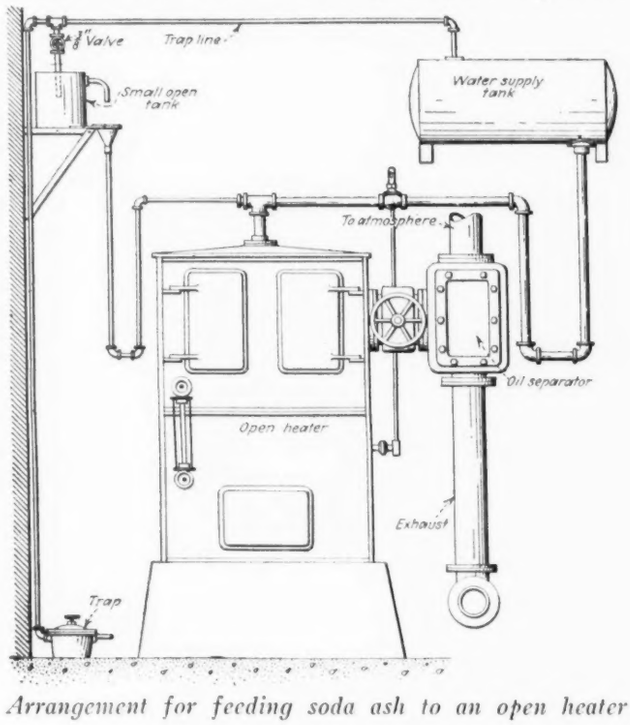
Los Angeles, Calif.

Practical Method of Feeding Soda Ash

It occurred to me that the following description of a simple apparatus that we have used in our plant for feeding soda ash might be of interest to other engineers who are not fortunate enough to have water softeners or other up-to-date apparatus for feed-water treatment. Our boiler plant contains four horizontal return-tubular boilers of 1,500 sq.ft. of heating surface each. Our average load is around 10,000 lb. of steam per hour, so two boilers only are used.

After using many different kinds of boiler compounds with various results, I obtained permission to use soda ash, which is bought by the carload for manufacturing purposes. Our city water contains approximately 30 grains per gallon of scale-forming solids, consequently we were always fighting scale. Our first trial with the soda was to feed it into the suction line of the boiler-feed pump, but it soon clogged up the pump and the feed lines. Finally, we decided to pass it through the feed-water heater, and after making a few minor changes we adopted the idea shown in the sketch.

The small open tank above the heater, which in our case is an ordinary wash boiler, is kept filled with condensate from a trap discharge. The water that is fed to the tank mixes with the soda solution and overflows into a funnel connected to the top of the heater. Approximately 14 lb. of soda a day is used, and this is divided into three shafts. Each engineer puts his portion



Arrangement for feeding soda ash to an open heater

of soda into the tank when he comes on duty. Using condensate instead of hard water, no clogging takes place in the pipes and a more constant flow is maintained.

Close attention is paid to the feed-water heater, and as an abundant supply of exhaust steam is available, the temperature is never less than 210 deg. As a result we get most of the mud and lots of it, out of the heater. This crude-looking outfit has been in operation for about three years and has given good results.

London, Ont., Canada. J. W. REYNOLDS.

COMMENTS *from* READERS

Get the Facts—Then Go Ahead

IT WOULD seem axiomatic that the first step toward the solution of any problem is to identify the conditions of the problem to be solved. As the propounder of proverbs puts it, "In cooking a hare, first catch your hare." In other words, if we are to determine the best method of operating a boiler room, we must first determine the conditions to be met. And one of the foremost essentials is an accurate knowledge of load demand, continuously, from minute to minute, hourly, daily and seasonally. The first step, therefore, is to provide suitable means for continuously measuring the output from each boiler.

This seems to be so obvious as to be perhaps uncalled for, yet considerably more than one-half of all steam plants, according to an investigation by *Power* (Aug. 3, 1926), are without means of accurately measuring steam output.

One can hardly conceive an electric generating plant without means of determining its output of electric energy. One cannot imagine a factory of any sort so loosely run that no check is kept on the plant production. Few indeed, are the manufacturing enterprises today that do not keep tabs on the output of the factory workers individually.

It is necessary to keep such data in order to eliminate unproductive units. Even more fundamentally it is necessary to maintain such a system for the purpose of establishing a standard of operation—a code of management designed to render automatic the maintenance of reasonable efficiency.

So it should be in the boiler room.

But are such operating standards set up in the average boiler room? Has the engineer recourse to records of steam demand and output? Does he know the peculiarities of the demand at all times? Does he know the peculiarities of each of his boilers? Does he know the peculiarities of the fuel and water he must use? Does he experiment and determine how to meet the load conditions with the boiler capacity available under the difficulty, if any, imposed by the quality of labor, fuel and water available?

The first rule that the public-utility power-plant operator must learn to keep before him is "Keep the juice on the line!" Whatever happens, power must be kept on the lighting circuit, trolley line or third rail. It is the same with the boiler-room engineer in the industrial plant as in the central station. His potential is pounds of steam instead of voltage, but a drop in steam pressure may mean as serious a production loss to the industrial plant he serves as does a drop of voltage to the central-station system. The main job of the boiler-room engineer is to meet the demand for steam. And it is only close study of the characteristics of his plant through continual comparison of operating methods with the results, that arms him to meet emergencies.

The demand for steam can be determined from the total amount of steam generated by each boiler or by measuring the steam consumption of each department. Most industrial plants using steam-flow meters have adopted the latter practice.

By consulting these flow-meter records the operator is in a position to know the normal demand for steam at any given time a considerable period ahead. He is thereby enabled to manage the operation of his boilers to best advantage. He knows how many boilers will be required at such and such a time, when a given boiler can be dropped, when boilers should be banked and when a specified boiler can be shut down for cleaning. He is always ready and able to supply steam for the expected demand, or for any reasonable emergency.

With a steam-flow meter on each boiler he is intimately acquainted with the operating peculiarities of all his units. He knows actually, not merely theoretically, the rate of operation at which any given boiler in his plant should be operated for best efficiency. The fall of efficiency in various boilers is shown by the flow meter, and the operator is advised when each boiler needs cleaning. By juggling the load so as to secure most advantageous load distribution, the efficiency of the entire plant is promoted through proper load balance.

A fact to which some boiler-room operators seem to pay insufficient attention is the relation between boiler overload and maintenance costs. Under many conditions flexibility is a required characteristic of boiler performance. With suitable auxiliary equipment the rate of boiler load may be quickly and largely varied. It is, therefore, a temptation to the operator to pick up heavy loads on a minimum number of boilers and perhaps sustain this load for a longer period than is best for over-all economy.

Of course this excessive loading tends to deteriorate furnace arches and brickwork. Clinkers form which are hard to remove. Their removal is likely to cause damage to be done to the furnace lining and repair of boiler linings is expensive.

There is nothing essentially new in these facts. Most engineers no doubt fully realize that overloading is hard on furnace walls and brickwork. Yet it goes on, for the most part unnecessarily, simply because in nine cases out of ten there is no instantly available means by which the engineer can tell just what load he has on each boiler.

The boiler-room engineer must be equipped to know continuously what each unit is doing. Otherwise he cannot know what he is accomplishing on his own job. Without such equipment he cannot do justice to his plant, his employer or himself.

F. V. WETHERILL,
Philadelphia, Pa. The Brown Instrument Co.

What Caused the Pittings on the Journals of a New Turbine-Generator Unit?

SOME TIME ago I was called by a factory to erect a steam turbine-generator unit of about 2,000 kw. capacity made by a well-known English firm of turbine builders. From the general appearance of the parts it did not occur to me to have been anything but a new machine, but when I opened the cases containing the turbine and generator rotors, I was surprised to notice the journals pitted in several places. I drew the attention of the authorities concerned, but was assured that it was a new machine.

Now a little while ago I met an engineer connected with the turbine manufacturer referred to who also assured me as to the newness of the machine and attributed the pittings to some defect in forging. How can all the journals develop identical defects, as the pittings are nowhere except in the journals? The pittings are more pronounced at the generator end than at the steam end. Probably some readers of *Power* can enlighten me on this point, as it seems to me rather extraordinary since both the parties claim that the machine in question is a brand new one?

J. W. BAKER.

Calcutta, India.

* * * *

Why Do the Boilers Shake?

THE letters that have appeared recently in *Power* in response to the inquiry of Mr. Hewlet in the July 5 issue, "Why Do the Boilers Shake," have been interesting and helpful.

It seems to me that the article by C. A. Green in the Aug. 23 issue and that by J. O. Benefiel in the Aug. 30 issue hit the source of the trouble—pulsations in the flow of steam caused by cutoff of the engine when the pipe is too large or badly laid out as to turns and bends, the vibratory rate of piping coinciding with the strokes of the engine and single engine cutoff dominating greatest flow of steam.

These troubles are not present in plants where the piping is properly figured for the work to be done, unless the piping is temporarily oversize to take care of power units to be added later. One rarely finds it where a number of units are supplied with steam from the same line, unless they are all of the same speed and in step, such as would be the case of engines driving alternating-current generators, and then they are generally so locked in step that the cranks and cutoffs are sufficiently at variance to chop up the impulses to the vanishing point.

The vibration of boilers has been a serious matter to some and has cost many a dollar in repairs to boiler equipment, mostly brickwork. I know of one engine, placed in an institution in New York City, that was never accepted and final payment never made because it could not be used owing to the excessive vibration it set up in the entire steam line. The engine was a 32x30-in. 150 r.p.m. unit fed by an 8-in. line off the middle of a cross-header that fed two slower running and two faster engines, usually one slower and one faster engine being in service with absolutely no vibration; but the moment the offending unit was started, the vibrations became so excessive that it had to be shut down.

During the nine years this unit was in the plant, it had been changed from non-releasing to releasing valve gear and a large drum or receiver, five times the cylinder capacity, had been added near the cylinder all to no purpose. The engine was about to be scrapped when I suggested slipping a steel disk with a 6-in. orifice in the flange joint above the drum. This was finally tried out but they used a cone instead of a disk and had to reduce the opening to 2½ in. by successive steps. The 6-in. opening did nothing, a 4-in. got about half the vibration out, and a 3-in. most of it, but the 2½-in. eliminated it entirely and the pressure on the drum or receiver at the engine shows no more drop below boiler pressure, than was there before the cone was put in, nor does the indicator diagram show a slightly higher initial pressure.

The steam undoubtedly does drop in the drum or receiver about the time of cutoff, but flows steadily through the orifice and at the time of the next valve opening has reached a point when its momentum has begun to have the effect of impact which is taken through the quickly opened valve, and for a time was mistaken on the diagrams for compression. This engine is now in reliable full-load service with no sign of the vibration after more than seven years' operation.

About three years ago I visited a plant that had operated two and part of the time three engines, and knew naught of steam-pipe vibrations until they installed one engine to carry all the load. Then the fun began, with ruined brickwork, and vibrating braces and pipe hangers tied to the iron trusses of the roof. The jingle was more than musical, it was terrifying. I suggested an orifice disk in the line, midway between the boiler and engine, which was taken under advisement on Wednesday, but nothing was done.

On Monday morning the engine was started as usual, and when it had been brought up to speed, the operating engineer was mystified by what he called a deathlike stillness, and the steam pipe was as steady as a rock. He got the master mechanic on the phone and asked him to come to the engine room at once. His first word as he approached the engine room door was, "What have you shut down for?" "I haven't shut down," replied the operator, and when the chief got into the engine room and saw the engine running he gasped, "What has happened?" No one knew, the jingle was gone and all was quiet. The chief asked what had been done on the previous day (Sunday) and was told that Tony and Mike had washed out a boiler. The chief looked with suspicion at the big valve in the main header about halfway in the line and asked if anyone had fooled with that valve and got a negative answer, but he called for a ladder and when it was not found in its accustomed place he got after Tony, who replied, "I get em; I had yesterday, I shut big valve, stop hot water drop on me in boiler." Well the ladder was brought and upon taking hold of the valve it was found to be opened but 2½ turns, and upon opening it wider the same old vibration began. After satisfying himself that he had full steam pressure at the throttle with the valve shut to the point that eliminated the vibration, the valve was adjusted to that point and left there.

Since then I have stopped vibration at several plants by the use of orifice disks, using sometimes two disks, 10 to 15 ft. apart in the line. There are few things done in a steam plant where the results are so big and the expenditure so small. It may be significant to note that this trouble is never encountered in boilers feeding turbines, because the flow of steam is constant.

Passaic, N. J. E. E. CLOCK.

How Some Engineers "Get By"

ONE of man's greatest qualifications is to be able to work in harmony with his fellow creatures. This is particularly true of an engineer. His very position brings him in contact with people of varying natures, character, social standing and education. He who can adapt himself to each class as necessity arises, will not only be successful in his work, but also be liked by those who come in contact with him.

We can almost say that the young man who leaves school to take up his position in life, joining the ranks of those controlling the masses, must be a student of psychology. Hardly any two men can be handled alike, and he who studies and handles his men accordingly, will secure the greatest co-operation. Not only is this true of subordinates, but it also applies to superiors. It is not always that the men on top are faultless. On the contrary, they sometimes require far more study than the rank and file. They are in the position to command. Their ideas of plant administration or division of responsibility may be entirely wrong. It is better in such cases to play the game with them, trying to alter their opinions in a gradual manner. There are many ways in which a clever young engineer, or in fact any young man, can secure and enjoy continuously the confidence of his superior. Help him in every way imaginable. Nothing can be done until you have inspired confidence. This confidence must be used sparingly and with tact.

When you started as an engineer for him, your rating, as far as he was concerned, was zero. It depended entirely on the engineer as to whether this index progressed in a positive or negative direction. Most of the bosses have little or no time to check each individual operation. Their efficiency barometer is the sum of the operating expenses and your qualifications as a co-worker. If the boss can say "That boy fits into our organization," you can be sure of success. If the old man likes you, you can be sure the rest of the organization will like you also. Take over the duties as engineer of his plant and work with him in the best interests of the firm. His system may be entirely contrary to general opinion, but if he wants it so, work with him to form a solid front.

Thus we arrive at the real issue of this discussion, namely, D. Duncan's grievance in the July 12 issue of *Power*. Had he followed out something like the foregoing, he would have had no trouble, and probably would now be in full charge of the plant.

I cannot help feeling that Mr. Duncan was out of place in calling the manager's attention to the defective steam line brackets. After all, the manager probably has the administration he likes best. Had Duncan gone on record to the superintendent, to the effect that the brackets of this particular line were in bad shape, he would have been covered against any emergency. If both the superintendent and the factory chief were satisfied with the condition of these brackets, I certainly should have been more than satisfied. Had the line subsequently come down, that would have been their funeral. The proof of the pudding lies in the fact that the manager permitted the superintendent to fire Duncan after the latter having, what he called, "worked for the interest of the concern."

It is no use bucking against strong combinations like these, unless one knows absolutely what one is doing. And then, there is only one way of accomplishing this, and that is to be diplomatic and use tact. Outshine them in every undertaking and go on record in everything you do. These records will back you up should anything go wrong. When you do this, you will generally find the other fellow doing the same, with the result that the firm's interests are taken care of better. S. A. INGE.

Buenos Aires, Argentine, S. A.

Answers to What Do You Know

The questions are on page 481

Ans. 1—One answer would be: Compare the new rod with the old one to find the spool location. But assuming the old rod to be unavailable, put the new rod on the pump with pistons assembled. Next place the steam piston in its midposition and place the valve rockshaft in a vertical position. The spool should now be shifted along the new rod until it comes under the rockshaft. Mark this position and drill the rod for the spool dowel pin or locking key.

Ans. 2—In the submerged pump the water in the passage from the valves to the cylinder barrel must be stopped and set in motion again at each plunger reversal. In small pumps the weight of this water is small, so the inertia effect is negligible, but in large pumps the action would produce violent pounding, to avoid which the suction valves are placed below the cylinder.

Ans. 3—A pump of which the water end consists of two cylinders placed end to end and in which a single plunger reciprocates, and has the two facing ends of the pump cylinders provided with stuffing boxes to prevent leakage around the plunger. This is called "an outside center packed pump." The "outside" means the pump plunger is packed outside the cylinder and "center" indicates that the stuffing boxes are between the two cylinder ends.

Ans. 4—In order to resist high pressure the parts must be made as small as possible and of cylindrical or spherical form. Consequently, instead of the valves being placed on a single large flat deck, each is located in a separate "pot."

Ans. 5—The high-pressure cylinder takes steam full stroke, but on the exhaust stroke the steam expands into the low-pressure cylinder. In other words, cutoff is brought about by the high-pressure piston reaching the end of its stroke and expansion occurs in the low-pressure cylinder.

Ans. 6—The pump end should be all iron, as ammonia attacks brass.

Ans. 7—To lengthen the stroke of a pump piston toward, say, the head end, increase the lost motion of the valve of the other pump cylinder, making the distance from the nut and the head-end side of the valve greater in case of inside nuts and the rear end in case of outside nuts.

Ans. 8—By running it slow the water velocity and the pressure drop through the suction valves will be low, giving a greater vacuum in the suction pipe to permit the water being lifted a greater distance.

Ans. 9.—The pump suction carries a condenser into which the steam cylinders exhaust through a set of tubes, while the water to the pump goes through the shell.

Ans. 10—Yes. The Marsh boiler feed pump is arranged with a deflector valve so that after the pump is started the exhaust steam is condensed and mingles with the water entering the water end.

Experiences with Pulverized Coal

THE serial report on "Pulverized Fuel" just issued by the Prime Movers Committee, N.E.L.A., presents a comprehensive picture of pulverized coal practice from the viewpoints of design and operating data; also experiences of numerous companies are included. While there are now several hundred such installations of all sizes in service or building, only those serving boilers of 5,000 sq.ft. of heating surface and over are covered. Even with this limitation 203 plants are accounted for.

Of this number 80 are central stations (including central heating plants) and 123 industrial plants. In the utility field the central preparation system and the unit pulverizer appear about equally divided as to numbers, although the former accounts for much greater installed capacity. In the industrial plants, however, the unit type predominates in a ratio of about four to one. A few plants have both systems. Many of the unit type have gone into service during the last year. Expressed in numbers, the report shows 70 centralized systems and 133 unit systems. The latter would have been much higher had smaller installations been included.

The accompanying table showing pulverized costs and power consumption in several stations has been made up from data contained in the report. The total cost seems to run between 21 and 25 cents per ton, with one exception, the Narragansett plant, but in this case the cost of energy is not included. There is a wider range in the maintenance cost per ton.

A decided increase is noted in the use of water-cooled walls and radiant superheaters, especially in high load-factor plants operating at high ratings. Completely air-cooled walls are also being installed in some cases and in others a combination of water and air cooling is employed. Of the plants listed 73 have water-cooled walls, 80 air-cooled, 40 solid and the remainder combination.

Increasing use of air preheaters is also noticeable, there being 49 plants in the list so equipped.

Experiences of Operating Companies

The statements of operating companies with regard to experiences are unusually complete and contain much helpful information. Excerpts from a few of these statements are here quoted:

> REPORT of Prime Movers Committee contains accounts of operating difficulties and how they have been met. Survey of 203 plants shows large increase in unit systems.

"At the plants at Binghamton and Parr Shoals no attempt is made to pulverize undried coal, while at the Susquehanna River station it has been successfully milled and burned without drying. In most cases, if the moisture exceeds 2½ per cent, it is preferable to do some drying before the coal reaches the mill, as this facilitates handling and also decreases maintenance, although coal with 6 per cent moisture has been ground successfully, accompanied, however, by a decrease in mill tonnage. . . . Stellite faced feeder screws have been found to have twice the life of plain cast iron type."—*W. S. Barstow Management Assoc., Inc.*

Well-Type Furnaces and Unit System at Buffalo

"The Buffalo General Electric Company has, during the past year, installed in the Charles R. Huntley station four boilers equipped for burning pulverized coal. The furnace design is of the Fuller-Lehigh well type with Bailey water walls and Calumet burners. The fuel preparation equipment is of the direct-fired type, there being no storage of pulverized coal.

"A maximum evaporation of 250,000 lb. per hour per boiler has been obtained and each boiler may be operated at as low an output as 60,000 lb. per hour. As far as the furnace, the fuel preparation and the burning equipment are concerned, these figures are for continuous operation. The high rating corresponds to about 600 per cent of rated capacity based on the area of water-heating surface in both the boiler and water walls. At the extreme high rating slagging of the lower boiler tubes has been encountered. Additional Dialoy soot-blowing elements are now being tried in the bottom of the first pass in an effort to overcome this difficulty, and a different arrangement of drop-leg tubes is also being considered.

"No coal driers are included in the arrangement. The mills have successfully handled coal containing as much as 16 per cent surface moisture, but this wet coal puts a limit on capacity, depending upon the quantity of water, and arrangements are now being made to preheat the air to the mills on one boiler to determine the effects on capacity, operation and efficiency.

Cleveland Station Operates Without Driers

"No driers are used at the Lake Shore Station of the Cleveland Electric Illuminating Co., although moisture in the coal varies from 4 to 9 per cent, with monthly averages as high as 5.31 per cent. A small amount of trouble due to moisture was experienced during the first year with conveying systems and arching of coal in the bunkers, but this, however, did not interfere with continuous operation. The trouble with the conveying systems was eliminated by keeping the surrounding air above 65 to 70 deg. F., while the trouble with the feeders due to arching of coal was done away with by placing twenty-two ⅜-in. capscrews on the outside of the screw at 120 deg. apart. The pulverized coal bunkers are burned down and cleaned out every three months.

"Before using the capscrews on the feeders it was necessary to replace the feeders after about three months' use, but since using the capscrews the wear on the feeders has been practically eliminated, and it is necessary only to replace the capscrews every three months.

"The principal troubles now being experienced are with erosion on the exhauster fans, the piping between the mills and separators, and the mills. Exhauster fan blades last about 350 operating hours. Various grades of metal and rubber facing have been tried, but it has been found cheapest to purchase fan blades of boiler plate and have them installed by the plant maintenance crew. Eroded metal on exhauster fan housings is being replaced by welding at a considerable saving. Places which erode on the cyclone separators and connected piping are being

POWER CONSUMPTION AND PULVERIZING COST

Plant	City	Coal	Moisture as Rec'd., Per Cent	Moisture Leaving Driers, Per Cent	Mill	Power, Kw.-Hr. per Ton	Maint. Cents per Ton	Total Pulv. Cost per Ton, Cents
Susquehanna	Middletown, Pa.	Bit.	3	1.85	2 roller, 3 ball air transport	11.7–16.2	5	24
Lake Shore	Cleveland, O.	Bit.	4–9	No driers	Roller (screw trans.)	23.17 ave.	8.44	22.4
Columbia	Cincinnati, O.	W. Va. Bit.	3–6	1.75	Ball (screen screw trans)	20.8 ave.	6.56	20.9
Calumet	Chicago, Ill.	Ill. bit.	14.5	9.25	Ball air trans.	.....	.....	.....
Trenton Channel	Trenton, Mich.	Bit.	4.35	Not given	Roller and ball (air trans.)	22.14	6.33	22.76
Colfax	Pittsburgh, Pa.	Pitt. bit.	4.5	None	Roller (screw trans.)	22–24	3.29	.....
East Peoria	Peoria, Ill.	Bit.	15.04	7–8	Roller	25.77	8.24	21.18
South Street (Naragansett)	Providence, R. I.	Poca & New River	3–4	2.5	Roller (air and screw trans.)	16.85	5.16	17.03*

* Does not include cost of energy.

protected by a lining of scrap coal-conveyor belting which has lasted nine months so far and gives the appearance of a great deal further service."

Air-Cooled Furnaces Prove Satisfactory at Columbia

The Columbia Power Co., Cincinnati, states that "the coal received at the Columbia station in river barges contains from 3 to 4 per cent moisture; the coal reclaimed from storage contains from 4 to 6 per cent moisture, and experience has shown that for best overall operation the moisture content should be reduced to 1.75 per cent before milling. A higher moisture content before milling results in decreased milling capacity, increased energy consumption and difficulty with operation of the Fuller-Kinyon pumps.

"The air-cooled furnaces have proved satisfactory to date. It is essential for low furnace maintenance and continuity of operation to use a coal with a high ash fusing temperature. Furnace brickwork costs for the last five months of 1926 have averaged 0.465 cents per ton of coal burned, including labor and material."

Handling High Moisture at San Antonio

"Lignite coal as received at the Canal Station, San Antonio, averages 35 per cent moisture. After the coal is crushed, dried and pulverized, the moisture content averages 28 per cent. At present steam is used as the drying medium, but provisions are being made to pass a portion of the air from the preheaters through the driers and to use this hot air in conjunction with steam to dry the coal further.

"The moisture in the coal reduces the capacity of the pulverizing mills, closes the air ports in the driers, which eventually causes a shutdown of the mill until this wet coal can be removed, causes condensation on the sides of the screw conveyor housing, which in turn causes the coal to stick to the sides of the housing and clog the vents, and also causes the feeder screws to clog and feed unevenly. Coal then enters the furnace in a lumpy condition and not in the finely divided dust which is necessary for good furnace operation. This moisture also cuts down the efficiency of the boiler and imposes overload on the draft fan at high ratings. The air ports in the driers are cleaned daily, by hand. This takes the mill out of operation about two hours and uses one man's time for this period. The conveyor housing and vents have to be cleaned weekly if the weather is cold. The above troubles caused by moisture in the coal are not serious, but are annoying at times.

"The original burner nozzles, which were of the fantail type, had riffles on the discharge end for the purpose of spreading the coal at the burner outlet, and the burner casing had deflector plates in it to give a cross-current of air in small streams across the coal flow, causing agitation, turbulence and mixing at the burners. This arrangement was not satisfactory, consequently 8 in. was cut off of the riffle end of the burner nozzle, making this nozzle plain, and the deflector plates were entirely removed. This allowed the coal from the burner nozzle to spead, fill the burner and mix with secondary air blow into the burner casing. The above change resulted in the production of a bright white flame of increased spread."

Conditions Met in Chicago

On account of the special characteristics of the fuel used by the Commonwealth Edison Co., Chicago, the experience of the others with pulverized fuel, and the data published, were felt to be insufficient as a guide for arriving at a decision regarding the use of pulverized fuel. Also because this company's plants are in or adjacent to thickly settled communities, the question of dust elimination is likely to be a more serious factor than with most of the pulverized fuel plants now in operation. The idea, therefore, of experimental installations was decided. The experiment involves both the bin feeder system and the direct system, both of these on radically different steam generating equipment. The first of these installations was first put into regular operation at Calument Station in November, 1926. The second, a direct system is in the course of erection.

Preliminary operation showed the necessity of certain corrective measures briefly described as follows:

"Coal deflectors were inserted between the feeders and the burners, and fillers put in the lower part of the burners to give a more uniform flow. Deflector plates were also put into the secondary air ports to decrease the area from 45 sq.in. to 27 sq.in., giving more turbulence and a shorter flame. Lance doors were put in along the throat of the ash hopper for the convenience of breaking off slag bridging. There is a tendency for slag to accumulate on the side walls, and when fused to run down the walls until the floor is reached, where it solidifies and forms a fillet which builds up and forms a ledge over the ends of the hopper throat. By increasing the air pressure on the side burners, which increases the flame travel, this fillet can be cut down. Ash-pits are emptied once a day.

"The tubes in the boiler, economizer and preheater rapidly become coated with fine ash, but the ash is of such a character that it is readily removed from the boiler and economizer tubes with the soot blowers.

"The coal delivered contains ordinarily about 14 to 15 per cent moisture. The drier takes out about 4.5 per cent and the mill between 1 and 2 per cent. This gives about 9 per cent moisture at the boiler. There has been no difficulty in burning this fuel with this amount of moisture.

"An objectionable amount of dust is at present discharged at the roof from the cyclone vents. The vent from the mill enters the suction side of the exhauster which discharges into the cyclones.

"Some trouble also has been experienced in the drier due to spontaneous combustion of hung-up coal.

"To give any specific conclusions on this experimental steam-generating unit would at this time be premature. It would appear from experience thus far that none of the operating difficulties are such that they cannot be handled satisfactorily by some means. The economic problem and dust elimination remain at this time the unsolved phases of the experiment."

Carbon in Ash at Trenton Channel

"Samples of ash from various points in the boiler setting have been taken consistently for several months to determine the per cent of carbon in the ash. A quart sample from the hopper under the last pass of each steam boiler has been taken daily and analyzed for per cent of carbon. Composite samples of the ash from the furnace bottoms and from the precipitator and uptake hoppers have been taken each week-day. The average from the hoppers at the bottom of the last pass was 26.84 per cent, that from the bottom of the furnace 1.57 and that from the precipitators and uptake hoppers 17.38 per cent. Ash removed directly from the flue gas during the test on Boiler No. 4 contained practically the same carbon content as the average for the ash in the precipitators and uptakes.

"The experimental flue-gas dust precipitator of the latest Cottrell type having proved satisfactory, a program is under way to complete the installation of these precipitators on all boilers. Three more have already been installed and construction is in progress on the remainder."

East Peoria Station

"The coal as received at the East Peoria Station of the Illinois Electric Power Co. during the past year carried 15.04 per cent moisture. About 7 per cent of this is removed in the waste gas driers and in the mills. When the moisture in the pulverized coal exceeds 8 or 9 per cent, there is trouble handling it in the feeders. Feeders continually plug and the Reeves drive belts and feeder motors are overloaded. When it is possible to get the moisture in the pulverized coal below 7 per cent, there is little trouble with uneven feed at the burners.

"A modified riffle type burner has been tried at this station, but there appears to be very little advantage in its use. However, a change in the design of the front wall secondary air openings has made a marked change in furnace conditions. It has caused the zone of highest temperature to move toward the burners and practically eliminated slagging troubles at the rear of the horizontal water screen."

"With the New River nut and slack

coal as used by the Narragansett Electric Lighting Co., Providence, it has been found that if the coal contains more than about 4 per cent total moisture, as it goes into the mills, there is likely to be trouble of a more or less serious nature somewhere in the system. This may take the form of fouling of the transport lines, or of trouble with the feeders due to coal sticking.

"The air washer system has kept the mill vents in a satisfactory condition as far as actual dust from the cyclones is concerned. Considerable muck, however, is deposited on the roof from the air washer vent. The drier vents are somewhat dusty at times, especially if the coal going through the driers is quite dry, and there are no means of eliminating this dust except to reduce the circulation of air through the driers. However, this condition occurs only a few months in the summer, when the moisture in the coal is between 2½ and 3 per cent. The pulverized coal bunker vents discharge an appreciable amount of dust, but so far this has not given any serious trouble and no eliminators of any kind have been provided.

"There has been little variation of flow of pulverized coal to the burners with constant feeder speed with dry coal. Increase in moisture above 2½ per cent causes considerable reduction in the amount of feed per revolution of feeder, and as this moisture increases there is a tendency for the feeders to feed intermittently, and in a few cases feeders have arched over and stopped feeding."

Experience with River Coal

At the Holtwood steam station of the Pennsylvania Water & Power Co., the preparation plant contains one rotary drier and three 57-in. screen type pulverizing mills.

Slightly more than one-third of the coal burned was anthracite that had been dredged from the bottom of the Susquehanna River. The average heating value of all the coal burned during the year was 12,350 B.t.u. per lb. The average moisture and ash contents of the coals burned were:

	Anthracite	Bituminous
Moisture, per cent	13.0	3.8
Ash, dry basis, per cent	16.7	11.1

The cost of boiler house maintenance labor and material for the year 1926 was as follows: (boiler feed and steam piping, pumps and regulators not included.)

	Cents per Net Ton of Coal
a. Breechings, flues, stacks, bunkers and ash equipment	1.69
b. Furnace lining, arches, doors, casing and settings	1.58
c. Boiler drums, headers, superheaters, water screens	0.90
d. Feeders, burners, fans, motors, combustion control	1.73

a. The three unlined steel stacks were painted externally during the year, and a short section of the ash sluiceway was relined.

b. About half of the front wall in each furnace was relined during the year. The deterioration of these walls appears a result from spalling, although there was evidence in one wall that the bonding tile were improperly supported.

c. There has been no water screen maintenance expense.

d. It was necessary to put studs in the feeder screws to maintain the feeder capacity. When the screws were worn, there was uneven feeding as well as a reduction in capacity. Burners have required no maintenance. Primary air fans have caused more trouble than should be necessary for such equipment. The cost of keeping feeder piping tight is of some moment. The combustion control required very little maintenance, although considerable time was spent on it that is classified as operation cost.

"The only trouble that has arisen in connection with boiler operation was the clogging with slag of the two lower rows of boiler tubes at high ratings when bituminous coal was being burned.

"The major difficulties in the operation of the coal preparation plant have been the use of river-bottom anthracite coal in the drier furnace, the performance of the drier, the dusting of the mill equipment, and inadequate crane facilities for the frequent mill maintenance required when river coal is being pulverized. It was found impossible to burn pulverized river coal in the drier furnace, and resort was had to hand-fired grates. The drier operation was further complicated by inadequate aëration of the coal inside the drier, which called for forcing the furnace fire. The drier performance was considerably bettered by the installation of more agitating blades inside the drier shell, whereby increased aëration of the coal was secured. Dusting of the mills has not been overcome."

Lignite Successfully Burned at Valmont

"The Valmont station completed its second year of operation with pulverized lignite on Dec. 1, 1926.

"One of the essential differences between this coal and other lignites and Eastern coals is in the nature of the moisture content. This coal having a total moisture content ranging from 20 to 30 per cent is nevertheless very dusty in handling, indicating that the moisture is largely present in chemical and mechanical combination and not as surface moisture.

"In the artificial drying of coal previous to pulverization, a series of tests on a miniature drier revealed that as long as temperatures of the drying gas are kept below about 250 deg. F. no fires will result. One test at 289 deg. F. fired the coal in forty minutes, while another at 301 deg. F. started a fire in 25 minutes. Another test at 411 deg. F. caused a fire to start in ten minutes. These tests were conducted with heated air. With waste flue gas, longer operating periods can be expected due to lower percentage of oxygen present in the drying medium. Slack coal passing through a ½-in. screen was used in these tests."

"Rapid yet uniform drying of the mass at comparatively low temperatures is necessary for proper handling of this class of coal. From three to five units reduction in the total moisture percentage is accomplished in waste heat type of driers used in this plant. The following operation is typical of the drier performance on this class of coal:

Test Number	1	2	3	4
Av. temp. gas to driers, deg. F	402	404	410	361
Av. temp. out of driers, deg. F	124	123	110	130
Av. temp. coal from driers, deg. F	123	121	120	117
Moisture in coal entering driers, per cent	23.13	27.17	27.01	21.11
Moisture in coal leaving driers, per cent	20.66	21.30	21.95	19.01
Moisture in coal leaving pulverizers, per cent	18.42	21.26	21.66	18.25

"It will be noted from the above tests that the coal leaving the driers is of fairly uniform moisture content despite the variance in total moisture of the entering coal.

"No difficulty has been experienced in the air transport or mechanical conveying by screw conveyors of undried lignite coals running from 20 to 25 per cent moisture. Clogging of the conveyors is unknown unless under severe weather conditions, where coal is exposed to rain and snow, the driers not being used to remove surface moisture.

"Due to the soft and friable nature of the coal itself and the low ash content of non-abrasive nature, milling costs are very low both as respects energy consumption and maintenance expense. Wear on mills, piping and conveying equipment is exceptionally slight in the face of experience of other plants operating with high-ash coals."

Welding Dissimilar Metals

DISCUSSING "Spot Welding of Dissimilar Metals," R. T. Gillette, in the September issue of the *General Electric Review*, offers the accompanying chart to show combinations of metals that have been successfully welded. Where the metals are dissimilar in heat and electrical conductivity, they are best welded by the use of two dissimilar electrodes such as one of copper and one of copper-tungsten alloy of high tungsten content.

METALS	ALUMINUM	ASCOLOY	BRASS	COPPER	GALVANIZED IRON	IRON	LEAD	MONEL	NICKEL	NICHROME	TIN PLATE	ZINC
ALUMINUM	•											
ASCOLOY		•		•	•	•		•	•	•	•	
BRASS			•	•	•	•		•	•	•	•	
COPPER		•	•	•	•	•		•	•	•	•	
GALVANIZED IRON		•	•	•	•	•		•	•	•	•	
IRON		•	•	•	•	•		•	•	•	•	
LEAD							•					
MONEL		•	•	•	•	•		•	•	•	•	
NICKEL		•	•	•	•	•		•	•	•	•	
NICHROME		•	•	•	•	•		•	•	•	•	
TIN PLATE		•	•	•	•	•		•	•	•		
ZINC												•

Progress in Research and Application Shown at Welding Convention

Detroit Meeting Covers Pressure Vessels, Welds for High Temperatures, and Steel Plate Work—American Society for Steel Treating, Institute of Metals and Automotive Engineers Meet Simultaneously

DISTINCT contributions to the art of welding, both scientific and practical, were made at the annual fall meeting of the American Welding Society held in Detroit, Sept. 19 to 22, inclusive. The technical sessions at the Hotel Book Cadillac were paralleled by an exhibition at Convention Hall, where 36 manufacturers displayed the latest welding equipment and demonstrated its operation. The welding exposition this year was part of National Steel and Machine Tool Exposition.

Other technical societies holding simultaneous conventions in Detroit were: American Society for Steel Treating, Institute of Metals and Society of Automotive Engineers.

American Welding Society papers of particular interest to *Power* readers, dealt with research on welds for high temperatures, improvements in the bend test for welds, a metallurgical study of welds, and welding in the design of steel plate work.

Approves Program for Testing Welded Pressure Vessels

A meeting of the Pressure Vessel Test Committee approved drafts of the program for testing welded pressure vessels at the Bureau of Standards. These plans are next to be passed upon by the A.S.M.E. Boiler Code Committee. The hope was expressed that work would soon start on these exhaustive tests which are to be sponsored by the A.S.M.E. and the American Bureau of Welding.

Two papers on airplane welding, presented Tuesday morning, were of general interest to engineers in other fields as an indication of the acceptance of welding where safety considerations are paramount. The papers on welded aircraft were presented by Mr. Maylot of the Stinson Aircraft Corp., Detroit, and J. B. Johnson of McCook Field. Both reported extremely satisfactory experience with welded fusilages.

Reports Elevated Temperature Tests

A paper on the bend test as applied to welded coupons, by W. B. Miller of the Union Carbide and Carbon Research Laboratories, is a step forward in the rational use of the simplest of all field tests and it is hoped more work will be undertaken to standardize this method. An abstract of this paper follows.

Bend Test as Applied to Welded Coupons

IT WILL be generally admitted that any test to evaluate the quality of a weld quickly and inexpensively is desirable. Welded coupons have often been tested by bending and measuring the angle of bend. This test usually reveals any lack of fusion, thus being a test of the welder. If the weld has been properly made, the test then becomes a rough measure of the inherent quality of the weld metal and the union of the weld and face metal.

For some time, on account of its simplicity, attention has been directed toward this test with the hope that it might possibly be standardized to the extent that it would yield quantitative data on the properties of welded steel. Most modern publications on materials of construction refer to the bend test as a rough-and-ready test of ductility, in all instances the angle of bend being taken as a measure of the ductility. According to Johnson's materials of construction, the bend test is a more severe test of the ductility than the tension test, but has not been so carefully standardized. Methods of starting and closing the bend vary considerably, and herein lies the main cause for discrepancy in this test. Owing to the congestion of metal it is believed that other measurements yield more definite data and are applicable to any bend specimen regardless of the method used in making the bend.

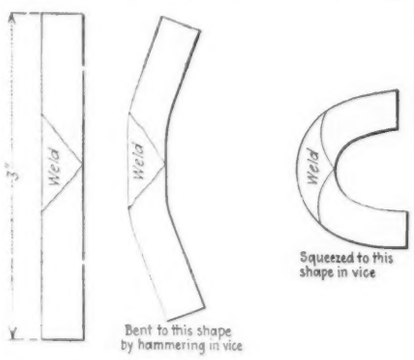


Fig. 1—Sequence of operation when making bend test with machinist vise

It has been observed for a long time that better bend tests and more consistent results were obtained when the bending operation was carried out in an ordinary machinist vise. The slow bending in the vise without any external pressure applied to the concave side of the specimen seems conducive to more consistent results. Perhaps the absence of the pressure on the concave side of the specimen allows the metal to flow more freely on this side, thus avoiding severe local stresses which otherwise cause premature failure.

In making bend tests in a vise, it is found that good results may be obtained on any length specimen by first initiating the bend about $\frac{1}{2}$ in. from each side of the weld by light hammering. The specimen is then inserted in the vise so as to bring pressure on the ends which causes the coupon to take on a uniform curvature as the vise is tightened, and the bending is continued until the first sign of cracking. The sequence of operation in bending short specimens is shown in Fig. 1.

Since the bend test is one of ductility, it was decided to measure it in terms of per cent elongation of outside fibers. For this purpose 10 straight lines, $\frac{1}{8}$ in. apart, were drawn across the specimen in the weld. By this means the per cent elongation of the outside fibers is measured directly over any gage length up to 1 in. or more. According to Johnson's materials of construction, if the neutral plane is considered to remain in the center of the piece being bent, the per cent elongation in the outside fiber is $\frac{100T}{2R}$, where T is the thickness of the specimen and R the radius of curvature of the neutral plane. Thus there are two methods of determining the per cent elongation of the outside fibers of a bend specimen: One by drawing a circle to coincide with the outside curvature of the bend specimen and calculating the elongation according to the foregoing formula; the other to establish gage marks before bending and actually measuring the extension with a thin flexible scale. Several bends were made on previously graduated specimens varying in width from three to six times their thickness, some being made in a vise and some on a

standard bending machine in which the coupon was wiped around a pin. The per cent elongation was measured directly over a gage length of 1 in. and was also calculated by the formula $\frac{100T}{2R}$. The method of calculation and of determining the radius R is shown in Fig. 2, which is an actual tracing of a bent coupon. The circle is drawn to coincide with about $1\frac{1}{4}$ in. of the outside curve of the weld or the length attained by the original 1 in. gage

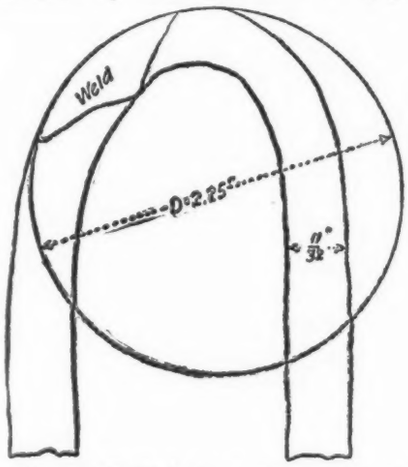


Fig. 2—Method of calculating per cent elongation

Per cent elongation $= \frac{100T}{2R}$

$2R = D - T = 2.35 - 0.344 = 1.906$
Elongation = 18 per cent

length. In the table is shown a comparison of measured and calculated values for per cent elongation over the weld area in each bend. The measured and computed values agree quite closely and indicate no appreciable shift of the neutral axis. Small variations in a circle diameter will produce large differences in per cent elongation, and when the difficulty of establishing the proper circle is considered, it is felt that the direct measurement is more simple and reliable.

If one were to judge the quality by the bend angle, it would be difficult to

PER CENT ELONGATION

Specimen No.	Measured	Computed	Difference
1	17.0	18.0	+ 1.0
2	15.0	14.3	− 0.7
3	30.0	26.2	− 3.8
4	17.0	15.9	− 1.1
5	22.0	20.9	− 1.1
6	16.0	15.4	− 0.6
7	13.0	14.5	+ 1.5
8	40.0	39.3	− 0.7

arrive at any satisfactory conclusion, but by measuring the per cent elongation directly, definite numerical values are obtained of the bending quality of the materials. The measuring of a bend angle, especially of welded specimens, leads to false assumptions, for equal bend angles have been found to give a large difference in per cent elongation of the outside fiber. Any gage length may be used, but one that takes in a little more than the width of the weld would appear most logical. Bending in a vise removes any possibility of severe local stresses, with possible premature failure, and may be successfully applied in specimens as short as 3 in. and up to $\frac{3}{8}$ in. or more thick. The ease with which this test can be made gives to it a great advantage and makes possible the field testing of a welder's product without any special equipment.

In the discussion of this paper it was suggested that the American Welding Society co-operate with the American Society for Testing Materials in setting up revised standards for the bend test.

On Tuesday afternoon was submitted a preliminary report of elevated temperature tests of welds as conducted by the San Francisco section of the Society. These tests are expected to yield data of direct value to designers of welded piping, pressure vessels and other equipment for high-temperature service in power plants, oil refineries, etc. An abstract of this paper follows:

Elevated Temperature Tests of Welds

THE San Francisco Section of the American Welding Society has undertaken, jointly with the Material Testing Laboratories of Leland Stanford, Jr., University, an investigation of the effect of elevated temperatures on the strength of welds in steel. The scope of these investigations covers the assembling and proving of equipment, preliminary tests of a number of specimens for the purpose of comparing various welding rods submitted, photomicrographic and chemical studies of specimens and rods used in the preliminary and final tests and a more thorough test of a limited number of welding rods in order to define more definitely the change of properties with change in temperature. The first two items of this comprehensive program have been completed and the results presented represent the first comprehensive series of tests made on welds at elevated temperatures.

Before the actual testing could be undertaken, it was necessary to first develop a special furnace for heating the test specimens and an extensometer for measuring elongations. Also, a considerable amount of study was necessary to determine the best method of measuring the temperature of the weld at the time of testing.

The special furnace designed for this work is shown in Fig. 1. It has a concentration of the heating element near each end that, together with the control used, afforded a convenient means of considerably flattening the temperature distribution curve of the specimen.

The question of taking the temperature of specimens was one that had to be worked out before any actual testing could be entered upon. The fact that the specimens were to be welded focused the attention upon the necessity for taking the temperature at the weld, which was approximately at the center of the length of the specimen. For comparative purposes a machined specimen was necessary, and therefore, no excess metal was available at the weld to offset even a very small hole for the placing of a thermocouple. After considerable thought and experiment a means was devised for clamping an exposed thermocouple in actual contact with the specimen at the weld. Tests were conducted to determine the exact inaccuracy of the exposed thermocouple, which showed that the clamp was 6 deg. hotter than the center of the specimen at approximately 950 deg. F. It was found necessary to clean the clamp of all heat color or oxidations at the contact surface for each new test. A second heat upon a set-up of specimen and clamp, without cleaning of either, showed a 12-deg. F. difference between specimen and clamp where the first trial showed only a 6 deg. difference. The clamp in no case showed a tendency to become loosened. This relationship and the temperature distribution in the specimen was determined on a substitute specimen made from the same material used in the test specimen and of the same dimension.

The extensometer was built to use one dial and to multiply the extension by two on the indicator. This has the advantage of simplifying the taking of reading and at the same time gives a high degree of sensibility, sufficient, with an Ames gage reading to 1/10,000 in. to afford more than the necessary accuracy.

All the specimens tested were prepared from plates cut from a 5x10-ft. sheet of $\frac{1}{2}$-in. firebox steel purchased in the open market. The location of each plate was recorded so that the position of the part of any specimen can be exactly determined in the original sheet should occasion demand. The center or reduced sections of the 1x16-in. speci-

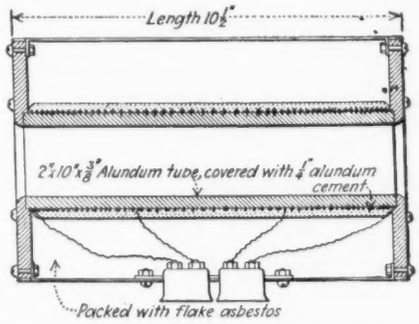


Fig. 1—Furnace for heating test specimen

men were machined parallel to within 0.001 in. All the electric welds were made by one man, and all but one of the acetylene welds were made by one welder, the one exception being a relatively new special rod for which the manufacturer supplied a welder. The plan of having one welder do each type of weld was resorted to in order to insure, so far as possible within the scope of the work, uniformity of the work done.

The welding rods used were classified in five groups—the first, low-carbon rods for gas welding; the second, low-

carbon electrodes; the third, high-carbon electrodes. The remaining two classifications have some special feature such as coating or other special distinction and for convenience were divided into electrodes and gas rods.

The results of the tests on these specimens made in a 100,000-lb. Olsen testing machine, are shown by the curves in Fig. 2. Each broken line in the graph joins two points, one of which represents a hot, and the other a cold specimen test at the two extremes of the test range. This was done in order to obtain a comparison from as many welding rods as possible. In Fig. 2 is also shown the result of tests on the original

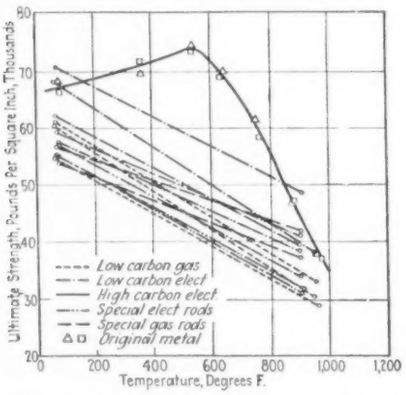


Fig. 2—Ultimate strength of welds at elevated temperatures

metals. Data for this curve were obtained at intermediate temperatures as shown by the test points plotted.

The results of these preliminary tests seem to indicate that as far as ultimate strength is concerned, a strong weld cold is in general also a strong weld hot. Fracture of a single scarf weld in a hot specimen gives evidence of originating at the narrow or bottom side of the weld and progressing to the opposite surface.

In the discussion Prof. Comfort Adams, founder of the Society, stressed the importance of research carried on by local sections as a means of enlarging the national influence of the Society.

In a paper on heat treatment by the oxyacetylene flame, F. E. Thum, associate editor of *Iron Age*, showed how the gas torch could be profitably employed for local heat treatment of poppet valves and other machine parts.

Metallurgical Study of Welds

Reporting the results of a metallurgical study of welds, G. R. Brophy, of the General Electric Research Laboratory, showed that the impurities in ordinary "tank" steel contaminated the weld metal so that the weld showed less strength than with a purer grade of parent-metal steel, such as "firebox." His experiments indicated that an increase of amperage with arc welding machines improved the quality of weld.

An interesting kink was described by Mr. Brophy. He showed that some of the good results of welding in an atmosphere of hydrogen could be obtained by the simple expedient of allowing a small stream of wood alcohol to trickle down the electrode. The alcohol vaporizes before reaching the weld and forms a protecting atmosphere, keeping out the oxygen and nitrogen of the atmosphere which might contaminate the molten metal.

The Wednesday morning session was devoted to the welding of freight cars and automobiles. In the afternoon members visited the River Rouge plant of the Ford Motor Company, and the Ford Airport.

Welding of Light-Gage Pressure Containers

On Thursday morning H. J. Grow, of the Air Reduction Sales Co., presented a paper on the production welding of light-gage pressure containers by the oxyacetylene process. L. J. Sforzini, of the Eastman Kodak Co., explained in detail the use of welding to fabricate a variety of work from flat steel plate. The examples presented included air ducts, breeching connections, hoppers, unusual piping connections, roof tanks, flash tanks, etc.

Two papers covering recent developments in the application of welding to the fabrication of steel-frame buildings were presented in the final technical session on Thursday afternoon.

The social features of the meeting included an Arabian ball, a dinner-dance, theater parties, etc.

Advantages of Using Surge Tanks

IN A recent report of the Hydraulic Power Committee of the National Electric Light Association it is stated that a surge tank is a necessary part of most modern medium or high head hydro-electric plants. With a long closed conduit, the introduction of a surge tank at or near the power house results in many advantages, as follows:

1. The total length of pressure conduit is greatly reduced. The excess energy in the long moving water column when shutting down a unit is, therefore, diverted away from the penstocks and waterwheels, and slowly throttled down at the tank, without the occurrence of dangerous pressure rises at any point in the system.

2. As has been demonstrated in the Peek formula, the reduction in length of pressure conduit permits for the same degree of speed regulation a substantial reduction in the flywheel effect required. Further, where it is possible to construct the surge tank close to the power house, the tank may replace both flywheel effect and relief valves, being in itself, when properly designed, a complete regulator. This type of installation cannot be made in the high-head plants of the West unless the tank is of the closed or air-chamber type, which has not found favor among the operating companies. The customary installation is a surge tank at the lower end of a tunnel which is run on a flat gradient and a penstock line equipped with pressure relief valve unless it is short in length.

3. When there is a demand for power, a supply of water is immediately available to the wheels to serve during the period required for accelerating the flow in the long pressure conduit leading to the tank.

4. The period of oscillation of a surge is greatly increased by the introduction of a surge tank. It is, therefore, easier for the governor to follow the surges and vary the opening of the turbine gates—or in the case of an impulse wheel, the power needle—and give to the wheel the necessary quantity of water for constant power under varying pressure.

An exact analysis of the surge tank should include a study of the action of the governor in keeping the power output constant while the surges still oscillate. When there is a downward surge there is a resultant drop in pressure, and it is necessary for the governor to open the turbine gates still more in order to keep the power output constant.

In addition, if the turbine is operating at a higher efficiency before the load increment is added than after, it is necessary to add more water than is required by the relation $Q \times H$. The modern turbine often operates at best efficiency at about three-quarter load, and there is a falling off in efficiency between this point and full load. This particular load increment should, therefore, receive special study if the plant is governing.

This action of the governor increases the amplitude of the surges, and where frequent load changes are made, as is likely to occur with a governing plant, a study of the surge tank should include allowance for load changes at about the quarter points of the period of oscillation of the surges. It is possible that a so-called non-spilling tank of the simple type will actually spill under these conditions, and unless provision has been made to take care of this, great damage may result. Simple tanks equipped with spillways limit the magnitude of the upward and thereby that of the downward surge, and the periodic surge is rapidly damped out. The dead-beat action of the differential-type tank is well known, and there is little or no possibility of trouble being experienced from this cause.

Special tanks without spillways, when built in the hour-glass shape, have characteristics similar to the simple tank with spillway in their ability to damp out periodic surges. The increased volume at the upper and lower levels materially restrict the amplitude of the surges, so that the surge-time curve is a much flattened sine wave with a broad crest.

Where the hydro-electric plant is operated on block load and is hand governed, the automatic action of the governor does not enter.

RECENT PUBLICATIONS

AMERICAN SOCIETY FOR TESTING MATERIALS. Report of Committee D-9 on Electrical Insulation Materials, 1927; 132 pages.

THIS pamphlet contains all of the methods of testing insulating materials prepared by Committee D-9 on electrical insulating materials and contains as well the annual report of the committee presented at the June meeting of the Society at French Lick, Ind., thus giving an idea of the various activities of the committee. In addition to the standards and tentative standards now in force there is included as an appendix to the report a description of the latest method of making the life test of transformer oils. This should be of particular interest to all oil companies. The pamphlet will make a very ready reference for any person interested in the most recent methods of testing insulating materials that are now in force.

Orders should be addressed to American Society for Testing Materials, 1315 Spruce St., Philadelphia, Pa.

HYDRAULICS. By Prof. E. W. Schoder, Cornell University, and Prof. F. M. Dawson, University of Kansas. Published by McGraw-Hill Book Co., Inc., 370 Seventh Ave., New York City, 1927. Cloth; 6x9 in.; 371 pages, 179 illustrations; 14 tables. Price, $3.50.

FOR those wishing a work dealing with practical everyday problems in hydraulics, this new book has much to recommend it. Although written primarily as a textbook, the treatment has the atmosphere of practical engineering activities. The material is of a general nature and not an exhaustive treatment of a few specialized subjects. This is emphasized by the nineteen chapters and five appendices into which the work is divided.

The treatment has been made in four stages, embracing a description of the physical phenomena, development of fundamental laws into useful formulas, presentation of numerous examples showing good form in analysis and methods in the solution of problems, and the inclusion of many typical practical engineering problems. The first six chapters treat of general subjects such as pressure against submerged surfaces, buoyancy and flotation, stability of dams, etc. There are nine chapters on the flow of water through nozzles, in pipe lines and open channels under various conditions. A chapter each has been devoted to the impulse-type waterwheel, the reaction-type waterwheel and centrifugal pumps. A table forming one of the appendices gives the result of 179 experiments to determine the head loss due to friction in various types of pipe.

Being a textbook on the general subject of hydraulics, the treatment is to a considerable extent mathematical. This presentation, however, is for the most part in simple algebraic terms and is easily grasped without a knowledge of advanced mathematics.

STEAM AND GAS TURBINES, with a Supplement on the Prospects of the Thermal Prime Mover. By Dr. A. Stodola, Professor at the Polytechnikum in Zurich. Authorized translation from the sixth German edition by Dr. Louis C. Loewenstein, Consulting Engineer. Published by the McGraw-Hill Book Company, Inc., New York, 1927. Two volumes, cloth boards; 7x10 inches; 1356 pages; fully illustrated, with 7 charts in pocket. Price, $15.

FOR years Stodola's monumental work has been regarded as the classic treatise and ultimate authority on many phases of the art of designing and building steam turbines. Unfortunately, this valuable material has been locked up, for many American engineers, in technical German. Doctor Loewenstein's translation of the second Germany edition has been useful during its more than twenty years of life, but meanwhile Doctor Stodola has greatly expanded the German text in keeping with the rapid growth of the art described.

It is almost superfluous to review in detail a work so well known to those interested in the turbine. For those who have not been so fortunate as to become acquainted with the text, it may be said that it opens with a discussion of thermodynamic principles and proceeds to an analysis of the flow of steam through straight and curved nozzles and bucket passages. A chapter on the conversion of energy in turbines is followed by a voluminous and detailed discussion of the construction of the most important turbine parts and a comprehensive description of steam-turbine types. Turbines for marine service and special purposes receive adequate attention. A chapter on condensers is a concise but thorough treatise on that important subject. Some twenty pages are devoted to a discussion of turbine operating experience with such difficulties as corrosion and wear and vibration. The steam-turbine section of the book ends with over two hundred pages given to the discussion of special problems in the mechanics and thermodynamics of the steam turbine.

The gas turbine chapter is followed by an illuminating discussion of the prospects of the thermal prime mover. The argument is involved and highly mathematical, but then one must recall that thermodynamics is a branch of mathematical physics, and the discussion of limiting possibilities is no superficial matter. However, having established the theory, the author proceeds to indicate how its findings coincide with those of common sense, and points out the possibilities and achievements of the turbine, the reciprocating steam engine, and the internal combustion engine. He then proceeds to discuss recently proposed improvements for steam plants, and the generation of electricity from coal in electrolytic batteries. The book closes with a profound discussion of the significance of the laws of thermodynamics.

BUSINESS CYCLES: THE PROBLEM AND ITS SETTING—The business cycle hazard is greatest in those industries dominated by large-scale business enterprises, and within those industries is greater among the larger than among the smaller enterprises—Wesley C. Mitchell, Director of Research, National Bureau Economic Research, Inc., New York City. Cloth, 6x9½ inches, pp. 512. Price, $6.50.

THE word has been passed around that the "business cycle" has been abolished. Some go so far as to declare that the "business cycle" to be a myth. What are the facts? The answer to this question has just been given by Professor Wesley C. Mitchell, one of the directors of research of the National Bureau of Economic Research Monumental though it is, the logical arrangement of the subject matter and Dr. Mitchell's lucid text, make it a delight to read.

This volume is divided into five great divisions. The first is a collection of theories on the subject of commercial crises and depression; the second division is a description of our present economic organization constituting in itself a short course in economics. The third division traces the development of the statistical approach to the study of business cycles and contains a most valuable critique of business indexes. The fourth division shows the contribution of business annals to the study of business cycles, and the fifth division presents a working concept of business cycles and a concise definition.

A section of the book that will be widely read, deals with indexes of business conditions. Charts are given to show eleven of the most important indexes of business conditions of various types, starting with Sir William Beveridge's chart of "The Pulse of the Nation" and coming down to the latest American Constructions. In his critique of the indexes of business conditions, Dr. Mitchell classifies them as relating to (1) pecuniary volume of business, (2) physical volume of trade or production, (3) "general" business conditions, and (4) forecasting sequences.

NEWS *of the* FIELD

Power System to Serve Jersey and Pennsylvania

Formation of one of the largest poolings of electric power facilities and output in the world, which will have a capacity in excess of 2,500,000 kw. and involving an expenditure of $26,000,000, has been arranged by the Philadelphia Electric Co., the Public Service Electric & Gas Co. of New Jersey, and the Pennsylvania Power and Light Co., according to an announcement just made Sept. 17 by Thomas N. McCarter, president of the Public Service Corporation.

The consolidation is expected to provide a wider use of electric current in rural sections and is regarded as one of the greatest electrifications of the farm movement ever undertaken.

The signing of the contract is looked upon by public utility men as the first step in a power generating scheme that eventually may cover most of the eastern section of the United States, supplying power to Atlantic coast cities from Baltimore to Boston. The chain is to be completed by 1930.

Three New Lines Planned

Three new high power transmission lines will be necessary to connect the companies. One, 82 miles in length, will be constructed from Siegfried, Pa., eight miles north of Allentown, to a switching station to be constructed at Roseland, N. J., which switching station will connect with the Kearny and other power plants of the public service.

A second line, 49 miles in length, will be built from Siegfried to a switching station to be erected near Philadelphia, where it will meet lines of the huge Conowingo, Md., station, now under construction and other Philadelphia electric stations. A third line will link Roseland and Philadelphia and will be for a distance of 77 miles.

Claims Cost Reduction

With economies thus effected it is claimed that there can be a saving of at least 10 per cent in the cost of generating, which is seen as resulting in a possible reduction in the cost of energy to large users.

An advantage, as pointed out, will be the possibility of concentrating production in the most efficient generation plants of the companies, irrespective of ownership. The pool, in effect, will form one great company as far as operation goes.

The Public Service Electric and Gas Co. gives electric and gas service to a population of more than 2,600,000 in New Jersey. The territory served includes the larger cities of the State and extends from the Hudson River opposite New York to the Delaware River opposite Philadelphia.

The Pennsylvania Power and Light Co. serves an important territory in eastern Pennsylvania, embracing a population of more than 1,000,000. Included in this territory are Allentown, Bethlehem, and the anthracite region around Wilkes-Barre, Scranton, Hazleton and Shamokin.

The Philadelphia Electric Co. serves that city and the surrounding counties. Its territory embraces a population of more than 3,000,000.

K. M. Irwin Is Promoted by United Gas Improvement Co.

Kilshaw M. Irwin, formerly assistant to the electrical engineer of the United Gas Improvement Co., Philadelphia, has assumed the post of mechanical

K. M. Irwin

engineer of the electrical department of that company.

Following his graduation from the Sheffield Scientific School of Yale University in 1915, Mr. Irwin entered the employ of the B. F. Sturtevant Co. He later joined the engineering staff of Stone & Webster, Inc., Boston, and subsequently was associated with Perry Barker, consulting engineer, of Boston.

It was in 1919 that Mr. Irwin joined the organization of the United Gas Improvement Co. as assistant to the electrical engineer.

He has served for five years as an active member of the Prime Movers Committee of the National Electric Light Association. In 1924 he served as chairman of the Prime Movers Committee of the Pennsylvania Electric Association.

Mr. Irwin is a member of the American Society of Mechanical Engineers.

Electrotechnical Men Elect Officers—Plan Activities

Meeting at Bellagio, Italy, Sept. 12, the International Electrotechnical Commission's committee of action elected new officers as follows: President, C. Feldmann, Delft, Holland; honorary president, Guido Semenza, of Italy, the retiring president; honorary secretary, Kenelm Edgcumbe, of Great Britain, *vice* Sir Richard Glazebrook, resigned. The next meeting was fixed for Stockholm, Sweden, in 1930.

Reports from the advisory committees of the commission were submitted to the committee of action before the delegates left Bellagio on Sept. 13 for their tour of Italian cities. These reports were to be finally acted upon at the plenary meeting of the commission in Rome on Sept. 22. At the banquet held on Sept. 10 the American delegates presented a bust of Benjamin Franklin to the Italian committee.

A meeting of officers of the International Electrotechnical Commission, the International Conference on Large Electric High-Tension Systems, the World Power Conference, the International Tramway Union and the consultative committee of the International Telephone and Telegraph Association has agreed to recommend the formation of a co-ordinating committee to meet at infrequent intervals to compile data and prevent overlapping of efforts. The I.E.C. is to function as a clearing house for all these bodies, which will recognize it as the authoritative body for international electrical standardization. At a meeting presided over by Mr. Instrom, of Sweden, the international standardization movement was discussed informally.

Industry to Submit Planks to National Parties

Seventy-five members of the Platform of American Industry Committee, called together by the National Association of Manufacturers, met recently in New York City and adopted fourteen planks for incorporation in the National platform to be submitted to both the Republican and Democratic parties next year.

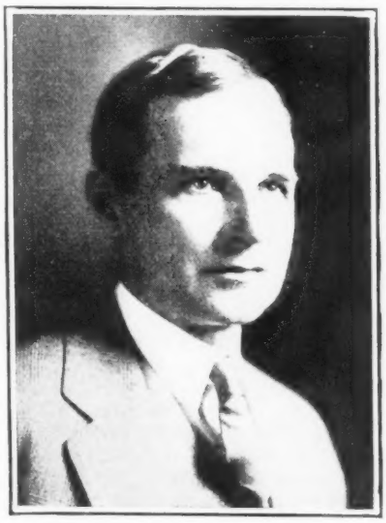
The planks include considerations on government and business, taxation, regulation of combinations, employment relations, transportation, immigration and naturalization, international relations, tariff, foreign trade policies, merchant marine, federal reserve bank system, waterways development, flood control and agriculture.

These fourteen planks will be drawn by as many sub-committees working under a general drafting committee.

H. C. Sutton Now U. G. I. Electrical Engineer

H. Craig Sutton, associated with the United Gas Improvement Co., Philadelphia, since 1913, has been appointed electrical engineer of that company, according to announcement Sept. 20.

Mr. Sutton received his engineering education at Cornell University and was



H. C. Sutton

graduated with the class of 1907. Previously to his joining the United Gas Improvement Co. fourteen years ago, he had been with the General Electric Co. at Schenectady, N. Y., and with the Oregon Power Co. at Eugene, Ore.

An active member of the Standardization of Electrical Practice Committee of the Public Utilities Commission of the State of Connecticut, Mr. Sutton serves also on the Power Line Construction Committee of the State of Pennsylvania, National Electric Light Association Committee on the Revision of the National Electrical Safety Code, and the Research Subcommittee of the American Committee on Electrolysis.

In addition to these activities Mr. Sutton is chairman of the Overhead Systems Committee of the National Electric Light Association.

Testing Pit Now Completed for Large Machinery

A pit which will permit the testing of the largest pieces of revolving machinery at runaway speeds with safety to the operators has just been completed at the Schenectady works of the General Electric Company. This pit, the largest of its kind ever constructed, will permit tests which cannot now be duplicated anywhere else in the world. It has been built for the purpose of running "double-speed tests" on the rotors of waterwheel generators, from the smallest size up to huge machines 40 feet in diameter and weighing as much as 500 tons. The pit itself is a circular chamber with a depth of 30 feet, surrounded by two concentric walls of heavily reinforced concrete, between which there is a cushion of soft sand. Over the top is placed a cover 8 feet thick, of reinforced concrete and steel plate, and around the rim two ring girders each 2½ feet deep. The pit is housed in a large brick and steel building, placed in a field a quarter of a mile from the nearest factory building.

Midwest Power Conference Plans Active Program

Plans for the third Midwest Power Conference, which will be held in Chicago, Feb. 14-17 inclusive, promise a program of importance to power engineers. The program committee, which has studied the power situation, has arranged a conference consisting of seven sessions.

The first day will be devoted to registration and addresses covering "social and technical aspects of power development." This session will portray the uses of power as applied to the home and public commercial situations. Two sessions on Feb. 15 will cover the relation of power development to flood control, including both the social and technical features. The subjects will embrace problems of the Mississippi Valley, the Colorado River and the St. Lawrence River.

Symposium on Program

The economics of power stations, particularly steam reheating and high pressure operation will be studied at two sessions the third day. A special feature of this program will be a symposium for public utility and manufacturing representatives.

On the fourth day there will be another session devoted to the subject of economics of power stations, taking into account largely the fuel problems of power plants. In line with the usual custom of the conference, one afternoon will be devoted to inspection trips to some of the best and most modern plants in the Chicago area. No definite list of plants have been prepared, although several are being considered. The annual banquet will be held Thursday evening Feb. 16.

The officers of the Conference having been recently elected are as follows: Maj. Rufus W. Putnam, chairman; Alex D. Bailey, vice-chairman; G. E. Pfisterer, secretary; K. A. Auty, treasurer.

Reports Simplified Practice on Iron and Steel Scrap

Reports of the first revision meeting of the standing committee in charge of Simplified Practice Recommendation No. 58, dealing with the classification of iron and steel scrap are now being sent to purchasers, dealers and users of iron and steel scrap for their approval and endorsement.

Copies of this simplified practice recommendation may be had by request to Division of Simplified Practice, Department of Commerce, Washington, D. C.

Frank C. Wight Dies, Edited Engineering News-Record

Frank C. Wight, editor of *Engineering News-Record*, one of the McGraw-Hill publications, who had served that journal and its predecessor, *Engineering News*, in an editorial capacity for twenty-one years, died at his home in Summit, New Jersey, Sept. 18. Mr. Wight had been ill for only a week with an infected throat.

Born in Washington, D. C., Feb. 26, 1882, Mr. Wight studied at Columbian (now George Washington) University, and later at Cornell, where he received the degree of Civil Engineer in 1904. After graduation he spent three years in the office of the engineer of bridges of the District of Columbia, his previous summer vacations having been spent in the District Surveyor's office. While on the staff of the engineer of bridges he had important service in the design and construction of the Piney Branch and Anacostia bridges and of the great Connecticut Avenue viaduct over Rock Creek valley.

Mr. Wight's entry into the field of technical journalism dated from December, 1906, at which time he became associate editor of *Engineering News*. For six years his main assignments were in the fields of concrete, general construction and river and harbor work. In 1913 he was promoted to the managing editorship of *Engineering News*, a position which he held until *Engineering News* and *Engineering Record* were consolidated in 1917. Four years later he became managing editor of the consolidated journal, and on Jan. 1, 1924, upon E. J. Mehren's withdrawal from editorial service to devote his time to executive management of the engineering unit of the McGraw-Hill publications, Mr .Wight was made editor of *Engineering News-Record*. This position he held at the time of his death.

Frank C. Wight

More Power for Sioux City

New equipment has been ordered for the Big Sioux River plant of the Sioux City, Iowa, Gas & Electric Co. A 10,000 kw. capacity turbo-generator, making the third in the power plant of the station, will be delivered next April. The work will be finished next summer. The United Gas Improvement Co. of Philadelphia, will have charge of the construction, with H. S. Hurlburt, engineer, supervising the installation and building.

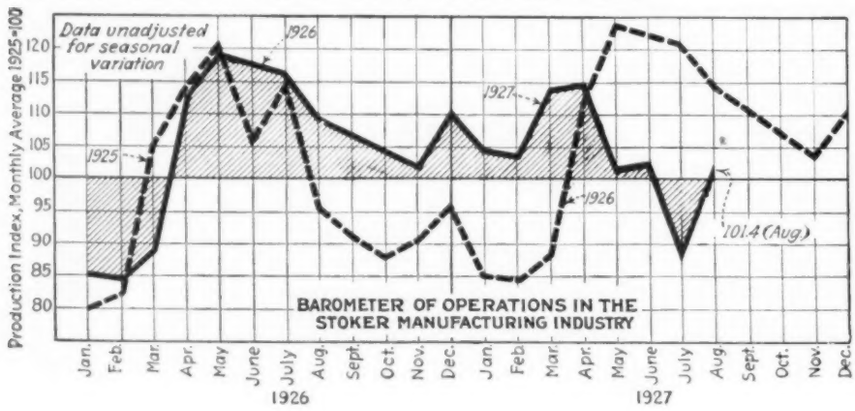
Stoker Production in Upward Trend Is Apparent

It appears that operations in the stoker manufacturing plants of the nation reached the low point in July, and that the close of the summer months witnessed a distinct upward trend in productive operations.

The actual stoker production during August was 15.7 per cent over that of July, but after corrections are made for the number of working days in the two months, it is found that the rate of production during August was only about 7.4 per cent over that of July. But the August operations of these plants were still about 14.3 per cent under those reported for August of last year.

Operations in the stoker manufacturing plants during the last summer do not appear to have followed the trends of past years. The peak of production during the current year was reached in April, thereby following the general trend established in both 1925 and 1926, but the operations subsequent to April during this year witnessed rather a drastic decline, reaching a low point in July, while in former years the high rate of production was maintained during the summer months. The actual production of stokers during the first eight months of the current year was 2.5 per cent under the production reported for the same period 1926, but was practically the same as reported for the first eight months of 1926.

The indications, therefore, are that the production of stokers during the current year taken as a whole will compare favorably both with 1925 and 1926.



Personal Mention

MATTHEW SLOAN, assistant inspector of boilers at Boston, was transferred to a similar position at New York, N. Y.

J. B. BASSETT, of the New York office of the General Electric Co., has been named executive engineer of the New York district.

CHARLES W. RUSSELL, assistant inspector of boilers at Providence, R. I., was transferred to a similar position at Boston, Mass., replacing Mr. Sloan.

W. J. HEINRITZ, who was formerly associated with the Sioux City Gas & Electric Co., Iowa, is now superintendent of the electrical department of the Southwestern Gas & Electric Co., Texarkana, Ark.

JAY W. MYERS, mechanical engineer, Tokyo, Japan, far-eastern representative for several American machinery manufacturing companies, has opened a branch office at Manila, Philippine Islands.

ELLIOTT A. ALLEN, mechanical engineer, has been appointed resident manager for the new branch engineering office of the New Departure Manufacturing Co. at 1812 Van Ness Ave., San Francisco.

T. F. BARTON, of the central-station engineering department of the General Electric Co. at Schenectady, has been appointed engineer of the New York district, with headquarters at 120 Broadway, New York, vice-president E. W. Allen has announced.

GEORGE F. MOSHER, assistant to the treasurer of the General Electric Co., has been named auditor of disbursements, succeeding C. H. Stull, who has become treasurer of the Ohio Contract Purchase Corp., an associated company, with headquarters in Cleveland.

RICHARD W. WOLF, who has been engaged for the last fourteen years in municipal engineering planning for the City of Chicago, has been appointed city engineer. Mr. Wolf is an active member of the American Society of Mechanical Engineers and the American Water Works Association.

G. E. LOFGREN, formerly engineer with the Combustion Engineering Corp., Montreal, Quebec, has joined the Ruths Accumulator Co., Inc., 292 Madison Ave., New York City.

LUTHER H. BOSNIAN has been appointed superintendent of the Park Street Plant of the Chain Belt Co., Milwaukee, manufacturers of REX conveyors, traveling water screens, chain and concrete mixers. Mr. Bosnian is a graduate of the Sheffield Scientific School, Yale University, and has been connected with the Chain Belt Co.'s production department for the last eight years. Previous to this he was with the Westinghouse Electric & Manufacturing Co. He came to the Chain Belt Co. in 1919 as a time study man.

W. B. WOODHOUSE, general manager of the Yorkshire Electric Power Co., and a past-president of the British Institution of Electrical Engineers, is visiting Canada and the United States this month to acquaint himself with recent electrical engineering progress. Mr. Woodhouse, who has been identified with the development of electric power in Great Britain, is president of the British Electrical Research Association, a past-president of the Electrical Development Association, and a British delegate to the International Electric Commission.

PROF. L. K. RAMZIN, director of the Thermotechnical Institute of Moscow, has arrived in the United States to make a study of American electric power stations. Professor Ramzin, accompanied by his assistant, A. I. Moroz, proposes to visit within the next three months a number of power plants and power-plant equipment works in various cities of the United States, including New York, Providence, Baltimore, Detroit, Chicago, St. Louis and Los Angeles. He expects, while studying American ways of fuel utilization, to bring about an exchange of technical information on the subject.

Business Notes

THE ALLEN-BRADLEY CO., Milwaukee, has placed on the market a complete line of alternating-current and direct-current push-button starters ranging from ¼ hp. to 10 hp., 220 volts direct current and 15 hp., 550 volts alternating current, giving complete protection to operator, motor and machinery.

THE WESTINGHOUSE ELECTRIC INTERNATIONAL CO. has announced the establishing of a new branch, to be known as the Compania Electrica Westinghouse de Chile, with activities in the countries of Chile and Bolivia. E. L. McCloskey, formerly manager for China of the Westinghouse Electric International Co., has been appointed manager of the new branch with headquarters at Santiago, Chile. He sailed for his new headquarters on August 27.

Trade Catalogs

PLUG VALVES—The Merco Nordstrom Valve Co., engineers and manufacturers, 11 West 42nd St., New York City, has issued five illustrated pamphlets covering the use of Merco Nordstrom plug valves in different industries. Plug valves applicable to the petroleum industry, gasoline extraction plants, chemical industries, gas plants and field equipment, and in the handling of slurries and slimes in "wet process" cement plants, are fully considered and treated of in these five separate bulletins.

STOKERS—The Master Engineering Corp., 405 Lexington Ave., New York City, treats of the Master Stoker in an illustrated folder bulletin. This stoker is designed to handle virtually any fuel, anthracite, coke breeze, free-burning bituminous, or sawdust and wood chips when mixed with other fuel. Fed into a hopper at the front of the boiler, either by hand or by a conveyor, the fuel is automatically measured out in "handfuls" and pulled down onto a platform where at timed intervals a cam-actuated spreader throws the "handfuls" into any of eight positions, following one another in rotation.

METALLIC AND SEMI-METALLIC PACKINGS—The Flex-Alloy Packing Co., 1321 Walnut St., Philadelphia, has published and is distributing Bulletin No. P100 devoted to a descriptive and illustrative treatment of the flexible metallic and semi-metallic packings manufactured by the company. Flex-Alloy is a resilient and flexible metallic packing. It is made of finely drawn alloy wire, which is insulated, lubricated with graphite and then woven and formed into triangular sections. This packing is all of the same general design, but is made from different kinds of alloy wire and interwoven fibers which are best adapted to different kinds of service for low and high pressures and temperatures for saturated steam, superheated steam, hot or cold water, oil, ammonia, air, gas, acid or other fluids.

SOLENOID OPERATED VALVES AND SERVO MOTORS—The Ruggles-Klingemann Manufacturing Co., Salem, Mass., Sales Office, 38 Chauncy St., Boston, in Section H, Page H-1 deals with Ruggles-Klingemann solenoid operated valves, including the removable interior type. These valves may be used for various requirements and where operation from remote points is desirable. They can be operated from a push button or switch, and also by means of a pressure or speed governor. This type of valve lends itself to be placed on the steam line of a steam-driven unit, with the solenoid to be connected across a power circuit, and on failure of current supply the valve is either automatically opened or closed. Valves, the bulletin states, may be supplied for pressures as high as 400 lb. and for service in connection with steam, water, gas and oil.

BOILERS—The Wickes Boiler Co., manufacturer of steam boilers, Saginaw, Mich., reports the special preparation of Bulletins No. 2-No. 10 treating of the design, construction, installation, operation and maintenance of vertical water-tube boilers, horizontal cross-drum water-tube boilers and horizontal return-tubular boilers. Bulletin No. 2 is entitled "The Steam Boiler Analyst"; No. 3, "Reducing Costs in the Boiler Room"; No. 4, "Magnitude and Prevention of Air Infiltration Losses"; No. 5, "Saving Coal in Steam Power Plants"; No. 6, "Utilization of Waste Heat for Steam Generation"; No. 7, "The Wickes Horizontal Cross-Drum Water Tube Boiler"; No. 8, The Wickes Horizontal Tubular Boiler"; and No. 10, "The Heat Balance as an Aid to Reducing Fuel Costs in the Boiler Room." These bulletins will be sent on request.

Coming Conventions

American Boiler Manufacturers Association, winter meeting, Hotel Cleveland, Cleveland, Feb. 7; A. C. Baker, sec., 801 Rockefeller Bldg.

American Society of Civil Engineers, fall meeting at Columbus, Ohio, Oct. 12-15; meeting headquarters will be at the Neil House; address F. H. Waring, Chief Engineer, State Department of Health, Columbus, Ohio.

American Society of Heating & Ventilating Engineers, hold general meeting in New York City, during 4th week in January; A. V. Hutchinson, sec., 29 W. 39th St., New York.

American Society of Refrigerating Engineers, annual convention in New York, Dec. 5-7; W. H. Ross, sec., 37 W. 39th St., New York City.

American Water Works Association, California Section, at San Jose, Oct. 5-8; Paul E. Magerstadt, sec., East Bay Water Co., Oakland; North Carolina Section, at Durham, Nov. 7-9; H. G. Baity, sec., Univ. North Carolina, Chapel Hill; Southwest Waterworks Association will meet at Hot Springs, Ark., Oct. 10; Lewis A. Quigley, sec., superintendent of City Waterworks, Fort Worth, Tex. Iowa Section, at Council Bluffs, Hotel Chieftain, Sept. 28-30; Jack J. Hinman, Jr., secretary, P.O. Box 313, Iowa City.

American Socity of Mechanical Engineers, convention during week of New York Power Show, New York City, Dec. 5-10; Calvin Rice, sec., 29 West 39th St., New York City.

Association of Edison Illuminating Co's, convention at Colorado Springs, Col.; Sept. 26-30.

Empire State Gas and Electric Association, meeting at Lakeside Club House, Lake Placid, N. Y.; Oct. 6-7; C. H. B. Chapin, sec., Grand Central Terminal, New York City.

National Association of Practical Refrigerating Engineers, Eighteenth annual convention and educational exhibition in Civic Convention Hall and headquarters Hotel Whitcomb, San Francisco, Calif., Nov. 29 to Dec. 2. H. Fox, 5707 W. Lake St., Chicago, Ill.

National District Heating Association, annual meeting in May; D. L. Gaskill, sec. 112 West 4th St., Greenville, Ohio.

National Fuels Meeting, under the auspices of the Fuels Division of the American Society of Mechanical Engineers, will be held at the Hotel Statler, St. Louis, Mo., Oct. 10-13. Address inquiries to William G. Christy, Citizens' Smoke Abatement League, Chamber of Commerce Bldg., St. Louis, Mo.

New York Power Show (National Exposition of Power and Mechanical Engineering) will be held at the Grand Central Palace, New York City, Dec. 5-10. Address inquiries to the International Exposition Co., Grand Central Palace.

Stoker Manufacturers Association, fall meeting at Buckwood Inn, Shawnee-on-Delaware, Pa., Sept. 26-28.

Fuel Prices

COAL

The following table shows the trend of the spot steam market in various coals, f.o.b. mines; mine run, except Pittsburgh gas slack:

Bituminous (Net Tons)	Market Quoting	Sept. 14 1927
Pool 1	New York	$2.50@$2.75
Smokeless	Boston	1.61
Clearfield	Boston	1.60@1.90
Somerset	Boston	1.70@2.00
Kanawha	Columbus	1.75@2.00
Hocking	Columbus	2.00@2.25
Pittsburgh	Pittsburgh	1.90@2.00
Pittsburgh gas slack	Pittsburgh	1.35@1.60
Franklin, Ill	Chicago	
Central, Ill	Chicago	
Ind. 4th Vein	Chicago	
West Ky	Louisville	1.40@1.65
S. E. Ky	Louisville	1.40@1.75
Big Seam	Birmingham	1.60@2.00
Anthracite (Gross Tons)		
Buckwheat No. 1	New York	3.15@3.50
Buckwheat No. 1	Philadelphia	3.50@3.75
Birdseye	New York	1.50@1.80

FUEL OIL

New York—Sept. 22, light oil, tank-car lots; 28@34 deg. Baumé, 5c. per gal.; 36@40 deg., 5½c. per gal. f.o.b. Bayonne, N. J.

St. Louis—Sept. 14, tank-car lots, f.o.b. St. Louis; 24@26 deg., $1.60 per bbl.; 26@28 deg., $1.65 per bbl.; 28@30 deg., $1.70 per bbl.; 30@32 deg., $1.75 per bbl.; 32@36 deg., gas oil, 4.276c. per gal.; 38@40 deg., 5.105c. per gal.

Pittsburgh—Sept. 13, f.o.b. local refinery; 30@34 deg., fuel oil, 4¾c. per gal.; 36@40 deg., fuel oil, 5c. per gal.

Philadelphia—Sept. 14, 26@30 deg., $2@$2.06 per bbl.; 13@19 deg., $1.68@$1.74 per bbl.; 22 plus, $1.79@$1.85; 27@30, $2.10@$2.16.

Cincinnati—Sept. 20, tank-car lots, f.o.b. local refinery, 24@26 deg. Baumé, 5½c. per gal.; 26@30 deg., 5½c. per gal.; 30@32 deg., 5¾c. per gal.

Chicago—Sept. 17, tank-car lots, f.o.b. Oklahoma, freight to Chicago, 90c. per bbl.; 24@26 deg., 87½c. per bbl.; 26@30 deg., 90c.; 30@32 deg., $1.00.

Boston—Sept. 19, tank-car lots, f.o.b. 12@14 deg. Baumé, 4½c. per gal; 28@32 deg., 5.8c. per gal.

Dallas—Sept. 17, f.o.b. local refiners, 26@30 deg., $1.45 per bbl.

NEW PLANT CONSTRUCTION

Calif., Los Angeles—Lilly-Fletcher Syndicate, c/o C. Thoren, 5615 West 4th St., Contr., awarded contract for the construction of a 13 story apartment building on Kenmore Ave. Estimated cost $1,250,000.

Ill., Chicago—Bryn Mawr Beach Hotel Co., B. Marshall, Archt. and V. Pres., 612 Sheridan Rd. Wilmette, plans a 17 story hotel and club building at Sheridan Rd. between Catalpha and Bryn Mawr Aves. here. Estimated cost $5,000,000. Bryn Mawr Beach Building Corp., will construct the building.

Ill., Chicago—E. M. Willoughby, 77 West Washington St., awarded contract for a 36 story office and stores building to Henry Ericsson Co., 228 North La Salle St.

Ill., Great Lakes—Bureau of Yards & Docks, Navy Dept., Washington, D. C., plans the construction of an electric light and power distribution system at Naval Training Station here.

Ill., Kenilworth—Village, is having plans prepared for waterworks improvements including filtration plant and pumping station. Estimated cost $50,000. Pearse, Greeley & Hansen, 6 North Michigan Ave., Chicago, Ill., are engineers.

Kan., Manhattan—State, H. E. Shrock, Bus. Mgr., Topeka, plans the construction of a power plant at Kansas State Agricultural School here. Estimated cost $325,000. C. D. Cuthbert, Topeka, is architect.

Mass., Dorchester (Boston P. O.)—Transit Dept., Boston, is having plans prepared for the construction of a heating plant, etc., here. Estimated cost $100,000. E. R. Springer, 1 Beacon St., Boston, is engineer.

Mich., Detroit—Boydell Bros. White Lead & Color Co., 432 East Lafayette St., had plans prepared for the construction of a paint factory including 30 x 40 ft. power house, etc. Halpin & Jewell, 1024 Hammond Bldg., are architects.

Mich., Detroit — Smith, Hinchman & Grylls, 800 Marquette Bldg., Archts. and Engrs., will receive bids until Oct. 4, for a 29, 35 and 40 story office building including steam heating and ventilation systems, boilers, elevators, etc. on Griswald St. for Union Trust Co., Union Trust Bldg. Estimated cost $8,000,000.

Miss., Hopewell—State Hospital Removal and Improvement and Land Sale Comm., R. L. Brown, Secy., Box 40, Jackson, will receive bids until Oct. 5, for the construction of a power house, etc., here.

Mo., Ironton—City plans an election Sept. 27 to vote $49,000 bonds for waterworks improvements including 100,000 gal. reservoir, pump house, 100 g.p.m. deep well pump, etc. W. A. Fuller Co., 1512 Railway Exchange Bldg., St. Louis, is engineer.

Mo., St. Louis—Knights of Pythias, c/o St. Louis Lodge Deputies Assn., will receive bids about Oct. 6, for the construction of a 15 story office and lodge building including steam heating system, etc. at Grand and Delmar Blvds. Estimated cost $1,000,000. Trueblood & Graf, Chemical Bldg., are architects.

Mo. St. Louis—Missouri Pacific R.R., Railway Exchange Bldg., awarded contract for the construction of a boiler house, etc. at Ewing Ave. and Missouri Pacific R.R. tracks to Gillespie and Daly, International Life Bldg. Estimated cost $90,000.

Mo., St. Louis—Polar Wave Ice & Fuel Co., 3636 Olive St., awarded contract for an ice and cold storage plant on Rutger St. to Gillespie & Daly, 722 Chestnut St. Estimated cost $50,000.

Neb., Wilbur—City defeated election to vote $35,000 bonds for a municipal electric light plant.

N. Y., New York—**Bellevue Hospital**, had plans prepared for a 7 story hospital including steam heating, refrigeration, and ventilation systems, boilers, pumps, elevators, etc. at 26th St. and First Ave. Estimated cost $2,000,000. McKimm, Mead & White, 101 Park Ave., are architects.

N. Y., New York — Dept. of Correction, Municipal Bldg., is having plans prepared for a 14 story detention house and prison including refrigeration plant, etc. at Greenwich and 6th Aves. Estimated cost $2,000,000. B. W. Levitan, 100 East 42nd St., is architect.

N. Y., New York—French Hospital, 450 West 34th St., will receive bids until Oct. 3, for the construction of a hospital and nurses' home including steam heating, refrigeration and ventilation systems, boilers, pumps, elevators, etc. at 8th Ave. and 29th to 30th Sts. Estimated cost $2,000,000. Crow Lewis & Wick, 200 5th Ave., are architects.

N. C., Charlotte—Charlotte Apartment House Corp., has acquired a site and plans the construction of an 8 or 10 story apartment. Estimated cost $1,000,000. Architect not announced.

O., Cleveland—St. Charles Roman Catholic Church, N. F. Monaghan, Wilbur Ave. and Ridge Rd., awarded contract for a school and power house on Wilbur Ave. to W. J. Schirmer Co., 1720 Euclid Ave. Estimated cost $150,000.

Okla., Mulhall — City plans an election Sept. 27, to vote $22,000 bonds for waterworks improvements including deep well pump, etc. F. B. King, 829 East Park St., Oklahoma City, is engineer.

Okla., Woodward—City had preliminary plans prepared for a 1,000 hp. Diesel engine addition to light and power plant. Estimated cost $100,000. Black & Veatch, Mutual Bldg., Kansas City, Mo., are engineers.

Oregon—R. L. Luper, State Irrigation Engineer, Salem, has prepared plans and estimates and made aplication for permit for a 700,000 acre ft. storage reservoir, also dam, 375 ft. high to convey 126,000 acre ft. of water from Owyhee River in Malheur County for Owyhee Malheur Irrigation Project. Estimated total cost approximately $17,500,000.

Pa., Philadelphia — Hahnemann Medical College and Hospital, W. E. Herring, Pres., 15th and Race Sts. plans the construction of a college and hospital at Broad and Race Sts. Estimated cost $2,000,000. H. H. Marshall, 37 West 43rd St., New York, N. Y. is architect. Pettitt & Ferris, 115 West 45th St., New York, N. Y., are engineers.

Pa., Philadelphia — Schultz & Weaver, Archts., c/o I. Stern, Franklin Sq. Bldg., having preliminary plans prepared for a 22 story co-operative apartment building at 18th and Rittenhouse Sts. Estimated cost $6,000,000.

Pa., Pittsburgh—Grant Building, Inc., W. J. Strassberger, Farmers Bank Bldg., awarded contract for a 35 story office building at Grant St. and Third and Fourth Aves. to Thompson Starrett Co., 250 Park Ave., New York, N. Y. Estimated cost $6,000,000.

Tex., Beaumont—Gulf States Utilities Co., J. G. Holtelaw, V. Pres., awarded contract for extensions and improvements to power plant on the Neches River to Stone & Webster, 49 Federal St., Boston, Mass. Estimated cost $1,000,000.

Tex., Beeville—Central Power & Light Co., will soon receive bids for the construction of an ice and cold storage plant. Estimated cost $100,000.

Tex., Corpus Christi—City, P. G. Lovenskiold, Mayor, plans shipping port improvements to double present capacity including docks, warehouse, also loading and unloading facilities and machinery. Estimated cost $1,500,000.

Tex., Eagle Pass—Crystal Ice Factory, c/o A. Kifuri, plans the construction of a 10 ton ice plant to replace fire loss. Estimated cost $45,000.

Tex., Glen Rose—City plans an election Oct. 3 to vote $66,000 bonds for waterworks improvements including artesian well, pumping station, etc. H. B. McAllister, 519 North 12th St., Waco, is consulting engineer.

Tex., Ozona—West Texas Utilities Co., Abilene, will build and ice plant here. Estimated cost $40,000. Private plans.

T. H. Pearl Harbor—Bureau of Yards & Docks, Navy Dept., Washington, D. C., will receive bids until Nov. 23, for the construction of a refrigeration plant at Naval Operating Base (Submarine Base) here.

Equipment Wanted

Air Compressor—C. B. McLean, Mayor and Bd. of Comrs., Wilson, N. C., will receive bids until Oct. 6, for a portable air compressor with equipment.

Air Compressors, Capstans, Etc. — New Zealand Government Railways, Wellington, N. Z., will receive bids until Jan. 12, 1928 for two motor driven air compressors, one 2 ton and one 1½ ton capstans, etc.

Boilers—I. E. Wilder, 1465 Bleury St., Montreal, Que., is in the market for two 100 to 125 hp. tubular boilers.

Boilers, Pumps, Etc.—Bureau of Yards & Docks, Navy Dept., Washington, D. C., will receive bids until Nov. 23 for boiler house equipment including portable firebox type boilers, fuel oil pumping and heating equipment, boiler feed pumps, feed water heater, motor driven centrifugal hot well pump, etc. at Naval Operating Base (Submarine Base) Pearl Harbor T. H.

Generator—P. O. Box 324, Chelmsford, Mass., is in the market for a 100 kw. generator, 230 v., d.c., 600 r.p.m.

Hoist, Etc.—J. Gruy, Hebbronville, Tex., wants quotations on a gasoline hoist, also bucket with sheaves, cables, etc.

Motors — Scott Bros., 418 Macomb St., Detroit, Mich., is in the market for motors, etc. for metal plating shop.

Pumping Engine, Etc.—Metropolitan Dist. Comm., 1 Ashburton Pl., Boston, Mass., will receive bids until Oct. 6 for a cross-compound engine and a 3,000,000 g.p.d. condensing pumping engine for Arlington pumping station, Arlington, Mass.

Pumping Equipment, Etc.—City of Osgood, Ind., will receive bids about Oct. 17 for pumping equipment, etc. for proposed waterworks system. Estimated cost $75,000.

Pumping Equipment — City of Junction, Tex., is in the market for pumping equipment for proposed waterworks improvements. Estimated cost $25,000.

Pumping Equipment — Mayor and City Council, Lake Forest, Ill., will receive bids until Oct. 11, for pumping equipment for proposed waterworks improvements.

Pumping System — A. S. Wright, Clk., Osage, Ia., will receive bids until Sept. 29, for a 400 g.p.m. air lift pumping system with 50 hp. motor, air compressors and all necessary equipment.

Pumping Unit—J. H. Haynes, Mayor, Mercedes, Tex., plans to purchase and install a pumping unit for proposed sewage disposal plant. Estimated total cost $31,300.

Pumping Unit—Mission Memorial Co., National Bank of Commerce Bldg., San Antonio, Tex., will probably be in the market for a pumping unit for proposed waterworks improvements.

Pumping Unit—J. Lehrer, Garwood, Tex., plans the installation of a pumping unit, etc. for proposed irrigation project. Estimated cost $60,000.

Pumps — D. D. Harrigan, Brady Bldg., San Antonio, Tex., will be in the market for electric pumps, of various sizes for proposed wells in connection with irrigation project. Estimated cost $50,000.

Pumps, Etc.—City of Eupora, Miss., will receive bids until Oct. 10 for two pumps, etc. for proposed waterworks improvements. Estimated cost $60,000.

Pumps, Etc—G. R. Marshall, Clk, Victoria, Va., will receive bids until Oct. 4 for two deep well pumps, etc. for proposed waterworks and sewage systems.

Transformers, Switches, Oil Circuit Breakers, Etc.—Dept. of Public Works, Supplies and Tenders Board, Wellington, N. Z., will receive bids until Nov. 29 for two sets of transformer oil drying and testing apparatus for Waikaremoana electric power scheme, also until Jan. 17, 1928 for current and potential transformers, 8 oil circuit breakers, 3 air break switches, 17 isolating switches and until Jan. 10, 1928, for switchgear with accessories.